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A study of the factors affecting quality and rate of spoilage of certain fresh vegetables held under ice refrigeration.

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A STUDY OF THE FACTORS AFFECTING QUALITY AND RATE OF SPOILAGE OF CERTAIN FRESH VEGETABLES HELD UNDER ICE REFRIGERATION

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INTRODUCTION

Certain vegetables have a very rapid rate of spoilage after harvest unless the environment in which they are held is regulated within relatively narrow limits. This factor is true even though such vegetables are produced close to their market and the time between harvest and consumption is reduced to a comparatively few hours.

Much of this spoilage is due to physiological, fungus or bacterial breakdown or chemical changes within the plant tissue. It has been shown by controlled research that such breakdowns and changes can be reduced by regulating the temperature, relative humidity and air circulation to which the vegetables are exposed after harvest and during the marketing process.

It was proposed to initiate and conduct investigations and to continue previous studies pertaining to the regulation of these factors in the economical market handling of certain vegetables when produced by nearby market gardeners.

It was further proposed that these studies include specifically asparagus, celery, lettuce and radishes.

Project Objectives:

1. To determine the effect of controlled temperature, relative humidity and air circulation on the physical characters and spoilage due to physiological reactions and various organisms.
2. To evaluate the methods of handling asparagus, celery, lettuce and radishes where ice is used as the refrigerant and to note the approximate time such vegetables can be held under controlled conditions from the viewpoint of consumer appeal.
3. To determine whether or not ice can be used economically as a refrigerant in the efficient and economical handling of asparagus, lettuce, celery and radishes on the part of the grower, wholesaler and retailer.

Project Procedure:

1. Studies pertaining to the objectives were set up at three points: (a)

selected growers, (b) selected wholesalers, and (c) selected retailers. In addition, controlled studies were also made at the University of Massachusetts.

2. Studies involved for each crop: (a) methods of precooling and icing on the farm, and the relationship of such practices to rate and degree of spoilage in subsequent normal market handling; (b) methods and procedure that were applicable to the regulation of temperature while produce is in transit from farm to market; (c) degree of temperature control of produce while on the wholesale market as related to methods of precooling and icing on farm and in transit, and (d) methods and procedure of regulating spoilage and shelf life at the retail store level by ice refrigeration as related to the previous handling on the farm, in transit and on the wholesale market.

All studies were correlated to weather conditions prior to and during the marketing period. All studies further

were evaluated against checks or nonrefrigerated methods of handling at the various points of evaluation--the farm, in transit, wholesale market and retail store.

REVIEW OF LITERATURE

The literature on ice refrigeration of vegetables is very extensive. Only pertinent material which is directly concerned with the several aspects of this project will be reported. A review of certain factors influencing ice refrigeration will be considered first.

Refrigeration which is the extraction of heat from a plant or animal material at a temperature lower than that of the surroundings is one of the most important processes in the vegetable industry. Refrigeration is accomplished when a cool body is brought near to a warm body according to the fundamental principle that heat always passes from a warm body to a cooler one, the exchange being capable of continuing until the two bodies are at the same temperature (16).

There are two principle types of refrigeration--natural and artificial. Natural refrigeration utilizes ice, ice water or ice and salt mixtures; artificial refrigeration makes use of refrigeration machinery. Cooling by ice is a very old process; it is effective because as the ice melts, it takes up great quantities of heat before the temperature changes. Each pound of ice in melting will absorb 144

B. t. u. of heat, which is its heat of fusion. A ton of ice will absorb 144 x 2,000 or 288,000 B. t. u. in melting (11).

According to Tressler and Evers (46), the standard unit of refrigerating capacity is known as a ton of refrigeration. The ton of refrigeration is derived on the basis of the removal of the latent heat of fusion from 2,000 lbs. of water at 32°F. in order to produce 2,000 lbs. of ice at the same temperature in twenty-four hours. The latent heat of fusion of ice is accepted as being 144 B. t. u. per pound; therefore, with 2,000 lbs. of water at 32°F. and the extraction of 144 B. t. u. from each pound, a total of 288,000 B. t. u. are removed to change a ton of water to a ton of ice at 32°F. The standard ton of refrigeration is, therefore, 288,000 B. t. u. per twenty-four hours or 12,000 B. t. u. per hour or 200 B. t. u. per minute.

The change of state which occurs when matter is transformed from the solid to the liquid phase is called melting or fusion. Hausmann and Slack (16) define the heat of fusion as the quantity of heat that must be given to a unit mass of a solid to melt it without a change of temperature.

Sensible heat may be defined as that heat which produces a rise of temperature as when a pan of water placed over a flame becomes hotter and hotter to the touch. Tressler

and Evers (46) caution one not to mistake this type of heat from another type known as latent heat of fusion, the latter being the quantity of heat required to change the state or condition under which a substance exists without changing its temperature, e. g., a definite quantity of heat must be transferred to ice at 32°F. to change it into water at the same temperature. This definite quantity of heat is known as the latent heat of fusion in going from the solid to the liquid state.

Temperature may be defined as the thermal condition of a body. Temperature indicates how hot or cold a substance is; that is, it is a measure of sensible heat. Temperature, therefore, gives only the intensity of heat and not the amount (46).

Heat is assigned units of measure. Truscott (47) states that a common constant is the British thermal unit. This he defines as the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at normal atmospheric pressure (14.7 lbs. per square inch).

Arnold (2) distinguishes between heat and temperature. He points out that temperature is the condition of a body which determines transfer of heat to or from other bodies while heat is a basic form of energy.

Platenius (35) emphasized the fact that refrigeration from ice is dependent upon the rate of meltage. It was reported by Scates (41) that the rate of ice meltage is not directly proportional to heat content of air but depends upon transfer of heat from air to ice surfaces. This observation was substantiated by Hausmann and Slack (16) who found that ice meltage rates increase with an increase in relative humidity of air as well as an increase in air velocity.

Humidity is a basic consideration in ice refrigeration. Relative humidity is defined by Hausmann and Slack (16) as the ratio between the amount of water vapor actually present and the amount necessary to produce saturation at the existing temperature. The relative humidity can also be expressed in terms of pressure since the pressure due to the vapor is approximately proportional to the amount of vapor present; thus, the relative humidity is the pressure which would be exerted by water vapor if the atmosphere were saturated at the existing temperature.

McDermott (25) explains the relationship between temperature and humidity in more detail. He notes that by cooling a vapor but maintaining it under a constant pressure, a temperature is reached where this pressure is maximum. He terms this the point of saturation and declares that further cooling will result in condensation.

Anderson (1) elaborates on McDermott's (25) statement and points out that the absolute quantity of vapor in the air is not important in evaporation, but rather, the relation between amount of vapor present and amount that could exist under the same conditions without having condensation.

Relation of Temperature to Deterioration of Certain Harvested Vegetables

Platenius (35) found close correlation between temperature and resulting spoilage in vegetables. He reports that in general, rate of deterioration increases with an increase of temperature. This worker maintains that the increment in rate of deterioration is more rapid in the low than in the high temperature range. Platenius (35) elaborates on this by stating that of the different factors contributing to the deterioration of lettuce, temperature is by far the most important one. The prevailing humidity may have a pronounced effect on the rate of breakdown, particularly on wilting, but ordinarily this factor is of little importance under commercial conditions because lettuce is seldom exposed to a relative humidity of less than 90% before it reaches the market.

Arnold (2) confirms observations by Platenius (35) when he noted that the factors affecting the keeping

qualities of fruits and vegetables are temperature, ventilation and humidity.

Two sources of heat have been described by Pentzer, Wiant and MacGillevray (32). These workers state that field heat or sensible heat, as it is sometimes called, is the amount of heat that a fruit or vegetable has at any particular time and is proportional to their temperature. It gets its name "field heat" because it is initially acquired in the field. They assert that the second source of heat, vital heat, in fruits and vegetables results from the vital processes going on in the tissues, and from this, it receives its name.

Benoy (3) reports in his studies on the respiration of vegetables at 30°C. (86°F.), asparagus respired at the highest rate, followed by lettuce, green beans, okra, green onion , carrot, tomato, beet, green mango and red pimento in descending order.

Platenius (34) found that the period for which vegetables can be held in storage is lengthened only very slightly when the temperature is lowered from 80° or 90° to 55°F. On the other hand, the life span may be increased very decidedly by a corresponding lowering of the temperature below 55°F. Any precooling method, therefore, is of little use unless cooling to temperatures below 55°F. can be accomplished.

Investigation by Sainsbury (40) has shown that the average life of apples held at 30°F. will be extended 35% over those held at 32°F., so the importance of two degrees in storage temperature should not be overlooked. Sainsbury's investigation has also shown that apples in boxes stacked directly on ground floors remain at a slightly higher temperature than those in the upper sections of the same stack. Because produce stacked on floors where there is a similar cold storage space beneath do not display this difference, it is generally assumed that the variation is due to transmission of heat from the earth into the boxes in direct contact with the floor.

Rose, et. al. (38) found that radishes keep best at a storage temperature of 32°F. and a relative humidity of 90 to 95%. Bunch radishes may be stored for ten days to two weeks, and the tops will still retain a fresh appearance if they are not crowded in storage and are free from surface moisture.

In later experiments, Rose, et. al. (38) reported that celery is best stored at a temperature of 31° or 32°F. with a humidity 90 to 95%, high enough to prevent wilting and with sufficient air circulation to keep the temperature at the top and bottom of the room as nearly equal as possible. Considerable heat is given

off by celery because of active respiration, and the air at the top of a storage room is likely to be three to four degrees warmer than at the bottom unless special precautions are taken to avoid such conditions.

Mallison and Pentzer (24) report that in their work with lettuce, the temperature in transit and the condition of the lettuce at the time of shipment are the chief determining factors in its successful transportation to market. According to Rose, et. al. (38) if lettuce is in good condition when stored, it can be expected to keep for two or three weeks. The best temperature for lettuce storage is 32°F. with a relative humidity of 90 to 95%. There is some evidence that it can be kept in better condition if ice is placed in the packages at the time of storage.

In storage experiments, Platenius (34) noted that holding vegetables at a temperature of 35°F. from a few days to several weeks had no noticeable effect on the subsequent rate of breakdown when these vegetables were later transferred to higher temperatures.

As Bisson, Jones and Robbins (5) have shown, the deterioration process in asparagus as evidenced by reduction in sugar and increase in fiber begins immediately after cutting. These processes were greatly retarded although not suspended by holding the asparagus at 33°F.

The changes proceeded in direct proportion to the temperature of the asparagus and were most rapid during the first twenty-four hours after cutting. A temperature of 41°F. was much superior to 56° and 77°F. in preserving quality, though not equal to 33°F. Cooling the asparagus as soon as possible after cutting is, therefore, a good practice from the viewpoint of preserving quality.

It was pointed out by Rose, et. al. (38) that fresh asparagus is not usually stored except temporarily when the market is overstocked. Experiments have shown, however, that it can be held successfully for three to four weeks at a temperature of 32°F. and a relative humidity of 85 to 90%. At this temperature, growth of the stalks, which takes place at higher temperatures, is practically nil. The original tenderness of fresh asparagus which at ordinary storeroom temperatures is lost soon after cutting owing to the formation of woody tissue is preserved at the lower temperature. Furthermore, the sugar content to which asparagus owes some of its flavor and which after cutting rapidly deminishes at higher temperatures, remains practically the same as when the asparagus is out if it is put in storage immediately after cutting; therefore, the sooner asparagus is placed in proper storage after harvest, the better will be its condition when used. The loss of water while in storage or transit

is likely to be great if the stalks are not placed on wet moss or other moist absorbent material placed in the bottoms of the crates.

Both microchemical and macrochemical studies by Bisson, Jones and Robbins (5) showed a general increase in the amount of fiber in the spears at all storage temperatures. This was shown in the number of lignified elements both in the pericycle and in the vascular bundles aslwell as in the percentage of crude fiber as ascertained by chemical analysis. The greatest increase (with one exception) in fiber at all temperatures comes during the first twenty-four hours after the asparagus was cut but was least at the lowest temperature and greatest at the highest temperature.

In storage experiments with lettuce, McKenzie (26) noted a 6.33% weight loss after forty-eight hours of storage at 77°F.; a 1.21% loss after sixty hours at 40°F. and a 1.21% loss after sixty-three hours at 32°F. He found a close correlation between the temperature and deterioration and concluded that the loss of weight was five times greater at 77°F. than at 32°F.

Effect of Humidity on Deterioration of Certain Harvested Vegetables

There are two periods in the storage life of

vegetables which should be considered in a discussion of moisture losses. Directly after vegetables are placed in storage, there is a period when they are at a higher temperature than the surrounding air. This is the period when they will lose moisture most rapidly. This is due to the difference in the pressure of the water vapor inside the vegetables and in the storage air (8). Comin (8) further asserts that there are two factors which are of primary importance in the storage of vegetables. The storage air temperature should be kept close to freezing, and the relative humidity should be maintained at a higher level.

Arnold (2) reports that the factors affecting the keeping qualities of fruits and vegetables are temperature, ventilation and humidity. Arnold (2) further recommends a relative humidity of about 85 to 90% for apples in order to prevent shriveling and a loss in weight. In a more detailed discussion, Rose, et. al (38) recommended that leafy vegetables and root crops be stored in a relative humidity of 90 to 95% and most other vegetables be kept at 85% to 90%.

It has been pointed out by Comin (8) that in the storage of vegetables, the vapor pressure deficit is responsible for the rate of transpiration. Both relative humidity and temperature affect vapor pressure of the air

within the intercellular spaces of the vegetable tissues and of the air surrounding the vegetables. The higher the temperature, the higher the vapor pressure will be. For this reason until the vegetables reach the same temperature as the surrounding storage air, they transpire rapidly. Naturally, the weight losses of vegetables are most rapid just after they are placed in cool storage. Platenius et. al. (36) in transpirational studies found that shrinkage rate was higher for leaf crops than root crops and stated further that large roots lose less weight than small ones on a percentage basis. These investigators concluded that vegetables which present large transpiring surfaces to the air such as lettuce and celery suffer more wilt than vegetables with a small transpiring surface exposed such as carrots and squash. Comin (8) reported that one effective method of reducing moisture loss from vegetables is to cover them or place them in closed but not sealed containers. This procedure confines the transpired moisture and thus tends to maintain a near-saturated atmosphere about the vegetables.

That vegetables lose weight most rapidly immediately after harvest was pointed out by Buetenik (39). He found that leaf lettuce stored at 32°F. and 95% relative humidity lost 3.7% of total weight in the first eight days of storage. Following this eight-day period, fourteen

additional days passed before another 3.7% weight loss occurred. Temperature and humidity conditions were maintained at the same levels as during the first storage period.

Patton and Miller (30) working with eight different vegetables observed rapid loss in weight in all vegetables at room temperature. These investigations noted that weight loss was somewhat reduced when vegetables were stored in artificial refrigeration and found no loss of weight when vegetables were packed in crushed ice. In addition, they observed that most of the vegetables packed in ice gained about 4% original weight.

Precooling Vegetables

Precooling has been defined recently by Fisher (12) as "the comparatively rapid reduction of the temperature of a commodity before shipment to or below that temperature which it might ultimately obtain during transit under conventional refrigeration practices".

Pentzer et. al. (31) states that the practical reasons for precooling in many cases are--first, to remove the field heat from the commodity so that transit temperatures will be lower during the first part of the trip, and, second, to refrigerate the load sufficiently so that it will require less ice in transit. By cooling asparagus

as soon as possible, Pentzer et. al. (31) also noted that several benefits were obtained that may not be apparent to the shipper or receiver. If temperatures in transit are sufficiently low, protection from spoilage organisms is afforded. This benefit is usually self-evident. Low temperatures likewise preserve the quality of asparagus. Another reason for cooling, therefore, is to keep the heat of respiration low. This is particularly important with asparagus for its respiration rate and heat-evolving capacity are extremely high.

Pentzer et. al. (32) points out that it has long been recognized that within certain definite limits, the higher the temperature, the faster fruits and vegetables will ripen and soften and the more rapidly disease micro-organisms will develop to the stage where serious damage is done to the commodity. It follows then that the more quickly these products are cooled after harvesting, the longer their commercial life should be. This is the aim of precooling. In recent years, precooling has been also resorted to as a method of pre-refrigerating the carload of produce so that less ice would be needed in transit, thereby permitting shipment under much lower refrigeration tariffs.

Platenius (35) found that the beneficial effects of precooling has been over-rated by some growers

and shippers. Precooling is less effective than might be expected because the cooling rate of lettuce is exceedingly slow when the lettuce is held in a cold storage room. Ordinarily, a minimum of thirty hours is required to lower the temperature of the lettuce to 40°F. During the intervening period, deterioration still proceeds at an appreciable rate. Also, the effect of precooling ceases soon after the crates are removed to a higher temperature.

In Mallison's (23) opinion, precooling, or a rapid temperature drop, is essential during warm weather. He states that there are at least three methods available. He has found room precooling to be slow. The maximum temperature drop of prepackaged produce in master containers under the best conditions is around one degree per hour. Hydrocooling is efficient and effective in giving a rapid temperature drop and is being used successfully on a commercial basis.

The limited experience with vacuum precooling in the produce field has been encouraging. So far, the use of precooling of prepackaged items has been on an experimental basis but results indicate that we should get as good results with produce in closed containers such as perforated cellophane bags, for example, as are being obtained commercially with lettuce in crates.

The ice bag in the master container or crushed ice loose over the prepackaged produce also does a good job of precooling. Both poor and good results have been reported with the ice bag. Mallison's experience has been generally satisfactory for twenty-four hours. He suspects that the poor results have been due to either an insufficient amount of ice or the produce has been held too long a time. The ice bag has definite limitations, and if these are understood, the results should be satisfactory.

For 1948, which is representative of the average, the Association of American Railroads showed that freight loss and damage payments for fresh fruits, vegetables and melons amounted to $20,469,970, and of this total, $11,848,216 was attributable to "causes which may be controlled in some measure by shipper cooperation". To a great extent, this means poor handling, loading practices and inadequate precooling (13).

Hydrocooling and cold-air cooling are the two methods of precooling which are commonly used in the vegetable growing industry. A brief review of hydrocooling will be considered first.

Rear (37) defines hydrocooling as refrigeration of vegetables with iced water or iced water sprays.

Perry (33) describes two types of water precool-

ing units. In the first, the crates are partially submerged while they are carried through a tank on a conveyor with some water spray or flood from above. In the other, the conveyor is above the tank water level, and entire reliance is placed on the overhead flood.

Boar (37) describes in more detail the first type of hydrocooler mentioned by Perry (33). He describes it as a portable unit some 30 ft. in length containing a tank of water over which runs a dropper-type conveyor for feeding packed crates of commodity through the machine. A large propeller-type pump recirculates about 2,000 gals. of water per minute which falls in the form of spray over the goods as they are conveyed through the machine. Refrigeration is supplied in the form of crushed ice, the machine being furnished with a crushing device to break up the 300-lb. blocks of ice as they are fed to it by the operator. The purpose, of course, is to supply crushed ice so that it will melt more rapidly and thus increase the rate of applying refrigeration. These machines will consume ice at the rate of 3 tns. per hour thus applying refrigeration at the rate of 72 tns. per twenty-four hours.

Cardinell (7) explains the operation of a stericooler which is very similar in operation to the overhead type of hydrocooler. Stericooler is a patented device designed to drench produce with ice water in which

a germicidal agent may be incorporated. When the water is maintained at 32°F. (0°C.) produce loses about forty degrees of field heat in ten to twenty minutes as it is conveyed through the machine.

The refrigeration required in a hydrocooler is, of course, dependent upon the temperature reduction of the commodity, the refrigeration losses from the unit, the pump energy input, the cooling of fresh water when the tank is initially filled and the ice unavoidably remaining at the end of the day's run (33).

Perry (33) cites an example of the amount of ice needed by a hydrocooler during the course of a day's operation which is of interest. Ice required for cooling the tank initially is 1 1/4 lbs. per gallons of 60°F. water, or 1900 lbs. for a 1500-gal. tank. For commodity cooling only, each 100 lbs. of produce cooled through ten degrees recuired 6.3 lbs. of ice. For maintaining a melting ice surface large enough to keep the water temperature at 34°F., a unit with a 1500-gal. tank handling 360 36-lb. crates per hour must have in it 1,000 to 1500 lbs. of ice which is largely unusable at the end of the day's run if the last crate is to be properly cooled. The ice meltage from a pump driven by a 5-h.p. motor is about 70 lbs. per hour. The refrigeration losses from this size of unit are equivalent to from 50 to 100 lbs. of ice per

hour. Thus in a six-hour run, cooling three cars of 608 crates, each weighing 36 lbs. through 40°F., the ice requirement would be about 20,000 lbs. or sixty-seven blocks. In practice, the usage ranges from 5,000 to 7,000 lbs. per car.

Perry (33) states that in addition to the direct engineering problems of heat transfer, commodity and water movement and construction, there are problems in the application of these units. One important factor is the possibility of spread of infection from diseased to healthy produce by the recirculating water. Obviously, infected bunches, spears or heads should, of course, be culled before going through the cooler. Although many of the types of organisms which may be carried into the water by vegetables at transit temperatures and humidities, it would be desirable to keep the water as clean as practicable by prewashing the produce and by continual addition of fresh water to dilute the dirt, suspended plant material and organisms which otherwise unavoidably accumulate.

Pentzer's (31) results using a tank filled with ice water for precooling of asparagus indicate that this method of cooling has advantages over the one of blowing cold air through the load. The principle advantage is the more rapid heat transfer, but the freshening effect of the cold water should have some value. Asparagus cooled

by standing in ice water weighed about 1 lb. more per crate than that handled in the usual way probably because of the water which is absorbed or carried with it. This additional moisture should assist in preserving its freshness. Inspection on arrival did not reveal that the ice water treatment had any deleterious effect contrary to the general belief that wetting the spears, particularly the tips, was harmful.

Perry (33) reported using the overhead type of hydrocooler with asparagus, cooling rates ranging from 0.1 to 0.33 degrees drop per minute per degree difference between commodity and water were obtained. The lower value was observed in early trials before the unit was perfected while the higher figure represents exceptionally favorable performance. With a rate of 0.3, the commodity can be brought from 76° to 40°F. with 34°F. water in seven minutes and to 36°F. in ten minutes. With a rate of 0.2, it will take ten minutes to reach 40°F. and fifteen minutes to reach 36°F.

Excepting the poor appearance of crates and labels which resulted from the extreme wetting, Perry (33) reports that asparagus in seven water-cooled cars carefully examined on arrival in New York from California were in better condition as regards to freedom from wilting, mold and bacterial soft rot than four air-cooled cars

shipped for comparison during the 1937 season. Although incipient decay was noted in a few spears in all cars, it was more pronounced in the air-cooled cars.

Rear (37) found in so far as speed of cooling is concerned, top icing does not produce the results that can be obtained with hydrocooling. Consequently, some commodities are hydrocooled before top icing. Perry (33) reports that freshness is promoted by water cooling for instead of the slight evaporation incidental to air cooling, there is a carryover and retention of about 1 lb. of water per crate.

In contrasting the refrigerating efficiencies of cold-air cooling and hydrocooling, Rear (37) found the immersion-type hydrocooler to be extremely efficient and rapid in operation. Goods such as asparagus are completely precooled in ten to twelve minutes as compared with about ten hours previously required with the car precooling method.

Zink (50) reported that using an overhead-type precooling machine, the water of the precooler being at approximately 35°F., the celery was precooled quickly and thoroughly. Using this method of celery preparation is highly satisfactory. Wilting and decay have been almost totally eliminated, and refrigeration costs have been reduced considerably. In order to bring the commodity below 40°F. in a hydrocooler in ten to fifteen minutes, Perry

(33) recommends that the water temperature must be below 36°F. preferably at or below 34°F. This requires ample cooling surface and high water velocities in the ice melting tank or refrigerant evaporator.

Perry (33) concludes that water-cooling units require only ten to sixteen minutes as compared to eight to fourteen hours for portable air-cooling units; the higher resultant humidities tend to favor freshness, and reasonable sanitation must be practiced if decay from contamination spread by dirty water is to be avoided.

Cold-air cooling is a second form of precooling; it is not used to any great extent in the vegetable growing industry here in Massachusetts but is of great importance to the growers in the West, mid-West, Southwest and South. A review of some of the more pertinent literature on cold-air cooling follows:

Lincoln (21) states that for a thorough understanding of the construction and operation of cold-air precoolers, one should have a knowledge of engineering, controled circulation of air, heat-producing capacities of produce and effect of relative humidity on quality of vegetables. Lincoln (21) briefly describes a typical cold-air precooler. He notes that usually an iced bunker is located at one end of a storage room. Cold air is blown from the top of the bunker across stacked produce in the

room. The refrigerated air returns to the bottom of the bunker for recirculation. On return, cold air passes through crates of produce and cools the commodity.

Pentzer (31) reports that precooling and shipment in fan cars have been used in lieu of package and body icing. Temperatures of about 35°F. were maintained in these loads. This method of shipping is employed for California dry-pack lettuce after it has been vacuum cooled. Vacuum cooling is particularly appreciable to leafy vegetables that have a large surface for evaporation of moisture in proportion to size. Oranges cooled only three degrees, tomatoes six degrees in the same length of time that lettuce cooled thirty-six degrees. High vacuums are employed, about 29.8 ins. to provide evaporating temperatures of about 32°F.

Dewey (9) points out a possible serious disadvantage of cooling vegetables by means of air blasts and vacuum as compared with crushed ice or ice-water cooling is the danger of excessive dehydration of the product. This may not be the problem when precooling or refrigeration is accomplished by contact icing or hydrocooling since water is more likely to be added to the product than removed.

In an experiment to compare the transit temperatures and the conditions upon arrival of asparagus

cooled by portable fans and asparagus cooled by standing in ice water before packing with a short period of precooling in the car, Pentzer (31) reported the following results. The asparagus precooled in the usual way by portable fans averaged 40.5°F. after eleven hours of fan precooling; that in the car precooled first with ice water and then by car precooling reached 40.1°F. in six hours; 38.8°F. in eight hours. The temperature in transit in these two cars shipped under standard refrigeration were about the same except at the top quarter-length position on the eighth and ninth days when the fan-cooled car was four to five degrees cooler than the car cooled with ice water and fans. The asparagus in both cars arrived in excellent condition--no difference between the two cars being discernible.

Pentzer (31) found that with asparagus, the refrigeration requirement for the heat of respiration is large. According to his investigations, the heat evolved during precooling from 70 to 40°F. in a period of twelve hours would approximately 297,000 B. t. u. This figure is obtained by assuming that the heat liberated is from the combusion or respiration of hexose sugars. The ice required to supply refrigeration for these two sources of heat together with other requirements for a carload of asparagus precooled from 70 to 40°F. in twelve hours with

fans would require 6,519 lbs. of ice.

As refrigeration of prepackaged vegetables before delivery to retail stores appears desirable, tests were made by Hardenburg (14) to determine the most rapid rate of cooling packages in a 35°F. produce cold room. Wax beans and peas were tested using three arrangements of packages--individual packages on shelves, twelve packages in a sealed shipping case and twelve packages out of the shipping case until just before delivery time proved to be the most rapid method of precooling the packaged vegetables.

Icing Packages and Loads of Vegetables

Patton (29) remarks that loss in fresh vegetables due to spoilage and changes in weight may be considerable during transportation and marketing. It has become a common marketing practice in certain parts of the country to ice produce such as lettuce, spinach and carrots at the time of harvesting in preparation for shipment. Produce packed in this manner and shipped in refrigerator cars reached our local market centers in first-class condition even though it may have been in transit for several days. The local producer must compete with this producer, and unless he uses some means of preserving the garden-fresh appearance of his products, he may find

that he cannot obtain the highest prices.

Mallison and Pentzer (23) report that the temperature of ice, as of any inert, nonliving substance, follows rather closely that of the surrounding air. In fact, ice responds more readily to a change in temperature of the surrounding air than does any other substance because of its low specific heat. If ice that has been stored at a low temperature is quickly placed in contact with lettuce or any other commodities ordinarily shipped with body ice, it is likely to cause freezing injury to the commodity. Although in many cases the temperature of the ice might not be sufficient to cause freezing injury, it does cause the commodity with which it comes in contact to freeze more quickly and severely when subsequently exposed to low temperatures. Fisher (12) warns that the principle precaution we must observe in using ice is to see that it is not much colder than 32°F. because of the danger of freezing that with which it comes in contact.

Lewis (20) maintains that small sizes of ice should be used in vegetable packages. He adds that large chunks might cut or bruise commodities when a crate cover is forced into place. Mallison and Pentzer (23) offer a word of caution if there is a bulge to crates which have been iced. The three bottom layers of a load should be placed on sides or damage might result from pressure of

top crates. They specify that this is particularly true when large sizes of crushed ice are used in packages. Spangler (44) reports that most shippers are now using snow or crushed ice over the tops of loads although some shippers still use block ice. The advantages of crushed or snow ice over block ice is that it causes less damage to packages during the transit period.

Rear (37) found for most commodities contact ice will reduce the temperature at all parts of the crate well under 40°F. within several hours. This is sufficiently rapid cooling for all practical purposes and faster than could be obtained with either car or house cooling.

Spangler (44) reports a recent development in protecting the lettuce with waxed or parchment paper so that the ice does not come in contact with the heads. One method not yet perfected commercially consists of placing the ice in a sort of envelope between the layers. Another method consists of folding a long strip of paper alternately back and forth over each layer of heads and each layer of ice so that the ice is between the folds of paper. The advantage claimed for keeping the ice from coming in direct contact with the lettuce is that the leaves are not ice bruised and that midribs of the outer leaves are not discolored.

Bratley (14) pointed out that when vegetables

were packaged in tight materials that retarded the transfer of heat, considerable refrigeration must be supplied to offset the slow diffusion of heat from them. He found that with green beans that only the bottom layer of packages in a refrigerated case was satisfactorily cooled if they were at room temperature when put in the case.

In a later paper, Spangler (44) states that most of the Western packers of lettuce now line their crates with waxed or parchment paper which covers the bottom, sides and ends and folds over the top. The paper liners protect the hands from dirt, mechanical injury, disease infection, keeps ice within the crate and aids in maintaining a lower temperature. Brown (6) found that by using various types of paper liners, the quality of produce may be preserved by providing mechanical protection against bruising, by preventing the loss of moisture, by preventing the spread of diseases and in some measures by delaying detrimental internal changes of a chemical nature. Brown (6) further states that products which are shipped in contact with water or ice if wrapped require a paper such as parchment or "whalehide", which will stand up under such conditions. These papers not only remain untorn when wet but provide the proper degree of ventilation and protection against desiccation for such products.

Wet strength paper liners placed in ice packages of vegetables are used extensively. Holbrook (17) defines wet strength papers as those which retain a substantial degree of their original strength properties after immersion in water. The term is generally applied specifically to paper which has been treated by beater or tub sizing with a urea formaldehyde or metamine-formaldehyde resin.

In his extensive work on paper wrappers, Brown (6) noted that the chemical effects resulting from the use of paper wrappers and liners are negligible. Wrappers do not prevent the conversion of sugar into starch in corn and peas, and they do not improve the quality of grapes to any marked degree. An exception to the effect of paper on chemical changes is that of oiled papers which are used to prevent apple scald. In a survey conducted by Brown (6), he found that most commission merchants and grocerymen favored the use of parchment paper for wrapping and lining boxes of certain vegetables. There were also certain objections. Some stated that there is a tendency to use such papers to conceal defects. Others favored the paper for protective purposes but not for display as the paper conceals the attractiveness of the products.

According to Pentzer (31), leafy vegetables

such as spinach, greens and lettuce and other perishable vegetables such as broccoli, cauliflower, sweet corn and peas require temperatures as close to 32°F. as can be obtained. By a combination of package icing, top icing or body icing and ice bunker refrigeration, rail shipments of lettuce can be held at 33° to 34°F. even in warm summer weather. Temperatures of 40°F. have been maintained in truck shipments of corn heavily body iced with about as much ice as corn.

Patton (29) reports that a study in his laboratory indicated that the method of handling vegetables from time of production to time of consumption was a factor in the rate of change in weight and nutritive value. The use of crushed ice refrigeration was found to be superior to the three other storage conditions tested; that is, exposed to air at room temperature (approximately 80°F.) on top of crushed ice in an open display case and in refrigeration at approximately 50°F. Most vegetables were inedible after ten days' storage at room temperature. Leafy vegetables such as swiss chard and lettuce lost weight and vitamin C quite rapidly when stored on top of ice and in refrigerators. The more compact vegetables such as cabbage, asparagus and peas lost less rapidly at those two storage conditions. The garden-fresh appearance,

original weight and a large percentage of vitamin C content was preserved for as long as ten days in vegetables packed in crushed ice. Kaloyereas (16) disagrees with Patton (29) in that he found it took a longer time to cool fruit in the car when ordinary ice is used and the temperatures never reach optimum conditions. There is a wide variation in temperature in the lower and upper parts of the car as well as a continuous increase of the average temperature during transit after the minimum temperature had been reached.

Mallison and Pentzer (23) found with lettuce that the contact of the package ice with the heads gives sufficient rapid cooling of the lettuce to make precooling by mechanical means unnecessary. Moreover, no significant saving in ice can be expected because of precooling since the ice meltage in transit of precooled and noncooled cars was practically the same. In the same paper, Mallison and Pentzer (23) noted that thirty to thirty-five pounds of finely crushed ice in the package was sufficient to provide the necessary quick cooling and the moisture needed to keep lettuce fresh and crisp. This quantity is small enough to induce no undue slackness of the pack when it has melted. A source of moisture inside the crate is required because the waxed paper liner prevents the entrance of water from

the melting top ice.

Ice Refrigeration on Retail Store Produce Counters

In the modern grocery chain store, according to Warren (48), it has been found necessary to keep all fruits and vegetables under refrigeration until they reach the consumer. Fruits and vegetables which are refrigerated are placed in storage coolers promptly upon arrival at the store. They stay in this storage cooler until they are removed to regular or refrigerated produce cases where they are displayed to customers.

Study of the losses and damage by Hauch (15) occasioned by the necessary trimming, sorting and reconditioning in retail stores has revealed that of each 100 lbs. (not including containers) received in stores, 36.1 lbs. of bunched beets, 32.3 lbs. of cauliflower, 20.4 lbs. of head lettuce and 14.8 lbs. of broccoli had to be disposed of as garbage.

The cost of operation of a vegetable display is of prime importance to the average retail grocer yet even though a display method is considerably lower in cost, other factors such as the amount of product loss due to trimming and dehydration and the general opinion of the consumer must be equally considered. The ice display involves high daily operational costs but also re-

sults in lower percentages of waste. The ice display appeals to the consumers; produce so displayed will sell (27).

Warren (48) has found that the quality of perishable products is improved when the employees of a store are trained in the proper handling of refrigeration facilities. This is especially true in the case of fresh vegetables and fruits. This requires a constant training program and strict established procedure to insure prompt handling from warehouse to truck and from truck to store and again in the handling of the products within the store.

Oesterle (27) in using a consumer panel of seven housewives found that on the average they repeatedly selected produce from the ice display as their choice over produce displayed in other manners. Patton (29) also reports that customers remarked concerning the attractive appearance of the iced vegetable display as a whole and concerning the fresh appearance and crispness of vegetables held in ice. These two stores were of the self-service type, and customers in general did not object to removing produce from the iced tray. Some vegetables such as green beans and peas did present a problem in handling when they were not packaged. It is suggested that moistureproof containers be used for displaying

such vegetables in crushed ice. The management of these two retail stores has recognized the value of the use of crushed ice in the overnight storage of vegetables. The results reported in this paper indicate that there is less waste from spoilage and sloughing, no shrinkage, some saving in time and labor and indication of increased sale due to the use of crushed ice in the display of fresh vegetables and overnight storage.

Hardenburg (14) reported that in using ice trays which consisted of 2 x 4 ft. metal trays 5 ins. deep with three to four inches of crushed ice (one-half inch to one-inch pieces)in them that they required replenishment only once during the day.

Oesterle (27) found that ice displays provided both low temperature and a high humidity by surrounding the produce with snow ice. The melting ice offered both an abundance of moisture and very low temperatures.

Oesterle (27) found that ice display cases seem to most nearly achieve the vital balance of high humidity and low temperature. Oesterle (27) in another part of the same paper notes that the ice display case was likewise a storage display, for in the evenings a layer of snow ice was spread over the vegetables and a heavy paper covering placed over the entire case. By

morning, the layer of ice was usually melted away exposing the vegetables for display. Throughout the day, it was necessary to replenish the snow ice surrounding the vegetables several times. During the trimming and rearranging period, the bottom layer of ice in the case was replenished and chopped up so that more of the melting surface was exposed.

Stelpflug (45) reports that many people still believe that display racks using crushed ice are better for produce retail use than are the mechanically refrigerated produce cases. He believes that ice is theoretically a good medium for refrigerating produce because it does refrigerate while giving moisture to the product. He believes, however, ice to be less satisfactory than mechanically refrigerated produce display cases for many reasons--ice is expensive; it is not always possible to secure crushed ice; it is impractical to attempt to keep the weekend leftovers on the display rack because there is no satisfactory means for keeping this product properly iced from Saturday night to Monday morning. Ice racks usually make for a mess in the area around the racks.

Pannkuk (28) draws the following conclusions in his experimental work on retail ice displays:

1. Iced produce minimized weight losses (a) no more wilted looking produce, (b)

shrinkage saving from 3% to 5%.

2. Cold temperature retains full vitamin content and flavor.
3. Investment low, capital free for fast-turning merchandise.
4. Sales appeal great (a) produce looks fresher, (b) sprinkling of ice enhances nature colors.
5. Sales potential is great. Many retail food stores have produce sales of 25% to 30 of the total store sales. This is accomplished through good merchandising.

MATERIALS AND METHODS

Packages of vegetables were iced in packing sheds at various farms in Massachusetts or in the packing shed at the University of Massachusetts, at Amherst. The crates or boxes of vegetables were then followed to the wholesale market as in the case of asparagus and celery or from the grower to the wholesale market and on to the retail store in the case of lettuce and radishes. Crate temperatures and various tests were made at critical times during the marketing operation and deterioration of the produce was noted.

Vegetables Used

In selecting vegetables for experiments, care was taken to include commodities which are representative of those commonly marketed in Massachusetts. Typical root, stem, leaf and seed crops were selected. The vegetables which were chosen represent a wide range of heat evolution capacities. The following four vegetables were used in these experiments (heat evolved per ton of vegetables at a storage temperature of 60°F. in a twenty-four hour period is listed with each product):

Asparagus (73,460 B. t. u.) Radishes (11,862 B. T. u.)
Lettuce (45,980 B. t. u.) Celery (13,520 B. t. u.)
(38).

Ice Grades

Crushed ice is known variously as sized, processed, shaved and bagged ice. To manufacture this ice, bar or cake ice is placed in a grinder which is equipped with hook teeth. From the grinder, pulverized ice is dumped into a large rotating wire drum. The crushed ice then drops through the wire into individual bins thereby separating the grades of processed or sized ice. The ice industry has standardized crushed ice into five grades according to the size of wire mesh through which ice will pass. The following list gives these grades with the designation used in this paper. The trade term which is

sometimes applied and the size of the mesh through which ice of a given grade will pass is also listed:

Grade	Designation Used in This Paper	Trade Term	Size of Wire Mesh
No. 1 ice	1#	snow ice	3/16"
No. 2 ice	2#	fine ice	1"
No. 3 ice	3#	medium ice	1 1/2"
No. 4 ice	4#	coarse ice	2"
No. 5 ice or run-of-the-line ice	5#	crushed ice	directly from grinder without sizing

Amounts of Ice Used in Containers

The amount and size of ice used for the various packs differed with the size of the container and the commodity being iced. The distance and time required for the produce to be moved through normal marketing channels was also taken into consideration.

Another variable was the placement of ice in the package and length of hydrocooling. Some vegetables were packed in containers with ice divided in three layers, some with two layers and some with ice placement on the top of the package only. To obtain further combinations, different grades of ice were used in some of the packages. In a number of experiments, the produce was hydrocooled in different types of hydrocoolers and for varying lengths of time. In many experiments, the packages were lined

with wet-strength paper before they were packed and iced. Packing and icing will be treated more in detail for specific experiments under PRESENTATION AND DISCUSSION OF DATA.

Thermometers and Use in Packages of Vegetables

Pentzer, Wiant and MacGillivray (32) in recording the temperatures in carloads of melons used electrical resistance thermometers connected through leads to a master cable equipped with a metal door plate upon which the car doors could be closed. Dewey (9) in his work with lettuce recorded the temperatures at the centers of the lettuce heads and of the air with the chambers during cooling by thermocouples.

Several other workers, (33), (14), (27), (38), (9), have used electrical resistance thermometers for recording package temperatures. All of these studies have been conducted in refrigerated rooms or in cars or trucks on long-distance shipments.

Glass or metal thermometers have not been used very extensively for obtaining package temperature. They are mainly used under laboratory conditions; however, Dewey (9) obtained the initial temperatures of cherries and grapes by means of a mercury thermometer placed in the tills and between the fruits.

Temperatures were taken with Weston all-metal

Fahrenheit thermometers (Fig. 1) throughout this experimental work. This type of thermometer has a circular dial which is 1 3/8" in diameter. Temperature is recorded on the glass-faced dial. The large dial was found to facilitate reading of temperatures, particularly when lighting was poor. The thermometer is equipped with an 8-in. stainless steel stem. Only the last two inches of the stem are sensitive to temperature. Temperature recording is guaranteed to be accurate to one-half of 1% over the total scale (0° to 180°F.).

Thermometers were placed in the center of a package with the stem end in the container and the face of the dial against the outside of the crate. Because of the localized sensitivity of the stem, temperatures were obtained six to eight inches inside the pack.

Temperature Recording Notes

Special care was used in placing thermometers in the crates of vegetables. In the experimental work with asparagus, the temperatures were obtained from the time of harvest up until the asparagus was bunched by inserting the thermometer 3 ins. into the base of the asparagus spear. At each hourly recording, ten such readings were taken on ten different spears. These ten readings were then averaged, and this average was taken as the temperature of the asparagus at that point in the experiment.

The same procedure was used in working with the other vegetables from the time of harvest up until they were packed in crates. From the point where the vegetables were packed in the crates, the placement of the thermometers varied depending upon the size and the location of the different grades of ice. The placement of the thermometers for each experiment will be discussed in more detail in the PRESENTATION AND DISCUSSION OF DATA. In any case, the temperature readings were obtained in each crate by inserting the thermometers in three different places throughout the crate. The needle on the dial was allowed to come to test and the temperature recorded. In paper lined crates, a small hole was punched in the paper, and the thermometer stem was inserted through the opening.

Pressure Tester and Use in Determining Fiber Content of Asparagus

The important factors of quality in asparagus are color, flavor and freedom from fibrousness. Although there is practically nothing in the literature on the objective determination of asparagus color and flavor, several methods for determining the fibrousness or toughness of raw and canned asparagus have been suggested (18).

Kramer (18) in using an adaptation of the pressure tester commonly used for measuring the firmness of fruits where the plunger was replaced by a piece of

stainless steel .017" thick received correlations that indicated that there is generally good agreement between fiber content, pressure values and organaleptic ratings.

Wilder (49) developed an instrument called the "Fiberometer" for measuring the fibrousness of canned asparagus. The instrument consists of a stainless steel wire to which a 3-lb. weight is attached. A stalk is considered tender to the point farthest from the tip that the wire will cut.

Working with raw asparagus, MacGillivray (22) used the conventional fruit pressure tester with 1/8" plunger and found the resistance increased with duration of season and distance from the tip. Lee and Sayre (19) reported a correlation of .900 between tenderometer readings and organaleptic tests. The tenderometer readings were obtained by filling the sample space with 4.5" stalks.

Smith and Kramer (43) presented a rapid method for determining the fibrous material in canned green asparagus and showed that the fiber content increases rapidly beyond the natural snapping point of the stalk. Values obtained by this method were not affected by various canning procedures. Fiber of fresh and frozen asparagus may be determined by the same method if it is preceded by a cooking treatment.

In carrying out this determination, a composite sample of five spears was used, four of them were used in the determination and the other was carried as a control. The four spears were treated in exactly the same way the other experimental asparagus was treated, and the control underwent no treatment at all.

The instrument used in making these determinations was an adaptation of the pressure tester commonly used for measuring the firmness of vegetables where the plunger was replaced by a piece of stainless steel .017" thick (Fig. 2). Pressure was applied on the instrument until the blade just cut into the asparagus spear. The reading on the scale at this point was noted and recorded. The determinations were all made approximately four inches from the tip of the spear.

Color Determination in Asparagus

The existing standards of the United States Department of Agriculture are almost entirely subjective in that they rely primarily on the judgment of a trained inspector. United States standards for raw green asparagus include only the factors of color and size with the exception of factors that may be considered as defects. The color factor has no definition except a statement that a given length of the stalk must be green (18).

Scott, Kramer and Guyer (42) found the green

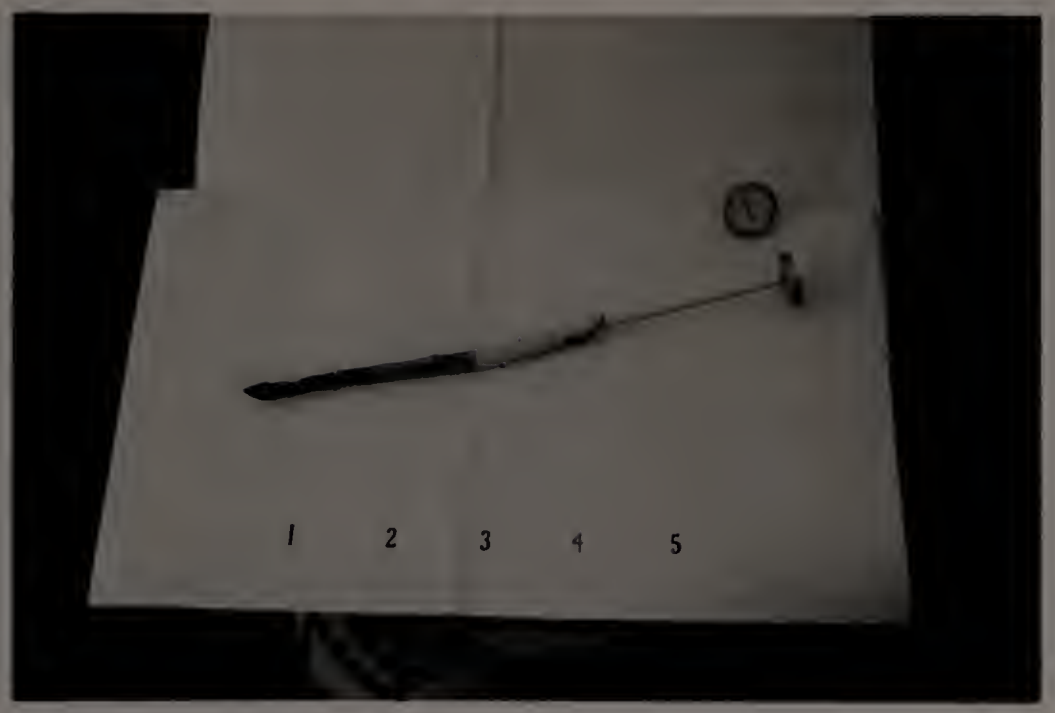

Figure I
Weston All-metal Thermometer
Used in Experimental Work

Figure 2
Pressure Tester and Blade Used In
Testing Toughness of Asparagus Spears

color of the asparagus spears to decrease during storage but the temperature of the storage had little effect on color.

In the case of color, it was impossible to check the contents of all the crates. Here a composite sample of ten spears was used in each experiment. Five of these spears were used for experimental purposes, and the other five were carried as controls. The color was evaluated using the 1-to-5 method, 1 being the green color of a freshly harvested asparagus spear.

The DICTIONARY OF COLOR by Maerz and Paul was used for color evaluation: Plate 19-K-3 was No. 1; Plate 20-K-5 was No. 2; Plate 20-L-3 was No. 3; Plate 20-L-8 was No. 4 and Plate 21-L-8 was No. 5. In matching unknown samples with some color in the Dictionary, the two surfaces to be compared were placed side by side on the same plane. Next, a piece of black paper 4" square with two holes 1 1/8" by 3/4" was placed over the sample so that it showed through one of the holes and the color used for comparison showed through the other hole (Fig. 3). All color comparisons were made on asparagus two inches from the tip of the stock. Matching of color during the day took place under clear north skylight, and all night color matching was done under artificial illumination--a three-cell electric flashlight.

Amount of Feathering in Asparagus - Notes

Here again, ten spears which represented a composite sample were selected in each experiment. Five of the spears were treated according to the experiment in progress, and the other five were carried as controls.

The amount of feathering was evaluated using the 1-to-5 method where 1 was a tight compact head. In an effort to keep results consistent, a photograph was taken of five spears of asparagus, each one representing one of the five grades (Fig. 4). This photograph was used as a standard of comparison throughout the experimental work.

Precooling Vegetables with Iced Water - Notes

Precooling with iced water will be referred to in this discussion as hydrocooling. Studies were conducted on three types of precooling units--overhead hydrocoolers, immersion-type hydrocoolers and cool-air precooling units. Produce was subjected to the different types of precooling units for varying lengths of time. The temperature of the produce was taken before and after hydrocooling.

Figures and Tables

Data is presented with accompanying figures and pictures. Figures are designated by Arabic numerals. Tables appearing in PRESENTATION AND DISCUSSION OF DATA

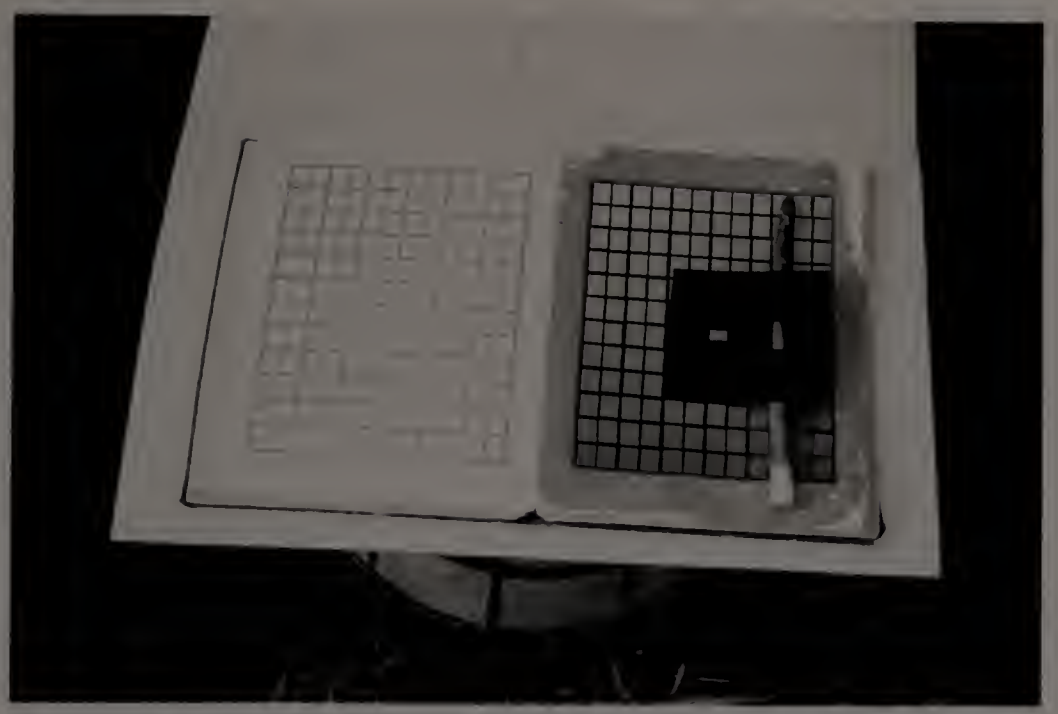

Figure 3
Method Used to Evaluate
Green Color of Asparagus Spears

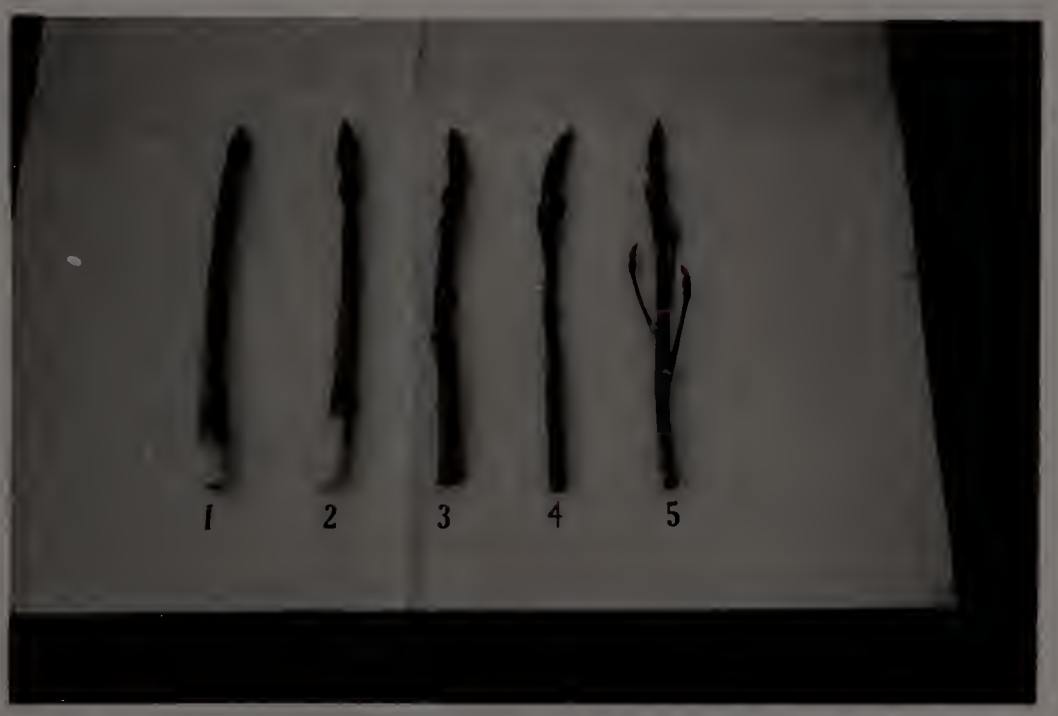

Figure 4
Picture Used for Comparison and Evaluation
of the Amount of Feathering of Asparagus Heads

are designated by Roman numerals.

PRESENTATION AND DISCUSSION OF DATA

Package Icing and Precooling Experiments

Experiments are reported in which vegetable packages were iced or precooled. Temperature and deterioration history of produce from the grower to a wholesale market then on to a retail store is noted on these containers. In some instances, the procedure of marketing is directly from the grower to the wholesale market omitting the retail market phase.

Each experiment reported was repeated five times; however, due to lack of space, only one of the five experiments was chosen because it is representative and will be discussed in the PRESENTATION AND DISCUSSION OF DATA.

Asparagus

Crates of bunched asparagus were iced and/or hydrocooled in an immersion-type hydrocooler (Fig. 5) during the seasons of 1950 and 1951 in the packing sheds of various growers throughout the Connecticut Valley and in the packing shed at the University of Massachusetts. The same evening of icing and/or hydrocooling, the packages were transported to the Boston Wholesale Market,

Figure 5
Immersion-type Hydrocooler Used In
Experimental Work with Asparagus

Figure 6
Overhead-type Hydrocooler Used In
Experimental Work with Lettuce

and arrived there at approximately 12:00 a.m. These experiments were conducted over a period of from twenty to twenty-two hours.

Methods of Packing, Icing and Hydrocooling

Asparagus was harvested between 6:00 and 8:00 a.m. Spears were graded, trimmed, bunched, packed, iced and/or hydrocooled. Two dozen 1-lb. bunches of asparagus were packed in each crate.

In each experiment, three crates of asparagus were used experimentally, and one crate of asparagus was untreated and carried through the experiment as a control.

History of Produce

Asparagus was packed, iced and/or hydrocooled between 11:00 a.m. and 1:00 p.m. At 3:00 p.m., the asparagus was picked up by the trucker and moved to his packing shed. Here the produce was transferred to a larger truck for the trip to Boston and arrived at the Boston Wholesale Market at aporoximately 12:00 a.m.

Asparagus - Experiment I

Top icing three crates of asparagus with 10 lbs. of No. 2 ice gave fairly satisfactory results with the temperature in all three experimental crates being maintained below the critical temperature of 55°F. through the marketing operation (Table A).

Temperature

TABLE A

Experiment I — Asparagus - Top Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	63°F.	63°F.	63°F.	63°F.	65°F.	63°F.	94	6:00 a.m.
In Field Boxes	2 hrs.	68°F.	68°F.	68°F.	68°F.	70°F.	66°F.	94	8:00 a.m.
In Packing Plant	3 hrs.	73°F.	73°F.	73°F.	73°F.	71°F.	70°F.	90	9:00 a.m.
After Bunching	5 hrs.	76°F.	77°F.	77°F.	77°F.	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	61°F.	61°F.	60°F.	78°F.	76°F.	80°F.	65	11:30 a.m.
After Icing	7 hrs.	48°F.	49°F.	48°F.	80°F.	80°F.	85°F.	56	1:00 p.m.
After Icing	8 hrs.	43°F.	44°F.	44°F.	85°F.	82°F.	86°F.	54	2:00 p.m.
Wholesale Market	18 hrs.	46°F.	47°F.	48°F.	84°F.	68°F.	70°F.	89	12:00 a.m.
Wholesale Market	19 hrs.	50°F.	47°F.	48°F.	81°F.	67°F.	70°F.	90	1:00 a.m.
Wholesale Market	20 hrs.	50°F.	54°F.	51°F.	79°F.	66°F.	70°F.	90	2:00 a.m.
Wholesale Market	21 hrs.	52°F.	53°F.	53°F.	78°F.	65°F.	69°F.	90	3:00 a.m.

Color

TABLE A-1

Experiment I — Asparagus - Top Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	2	1	1	2	1	1	1	1	65°F.	63°F.	90	6:00 a.m.
In Field Box	2 hrs.	1	1	2	1	1	3	1	1	1	1	70°F.	66°F.	94	8:00 a.m.
In Packing Plant	3 hrs.	1	1	2	1	1	3	1	1	1	1	71°F.	70°F.	90	9:00 a.m.
After Bunching	5 hrs.	1	1	2	1	1	3	1	1	2	1	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	1	1	3	2	1	3	1	1	2	2	76°F.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	2	1	3	2	1	4	1	2	2	2	68°F.	70°F.	89	12:00 a.m.

Amount of Feathering

TABLE A-2

Asparagus - Top Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Harvest Time	0 hrs.	1	1	1	1	1	2	1	1	1	1	65°F.	63°F.	90	6:00 a.m.
After Bunching	3 hrs.	1	1	1	1	1	2	1	1	1	1	71°F.	70°F.	90	9:00 a.m.
After Icing	5 hrs. 30 min.	1	1	1	1	1	2	1	1	1	1	76°F.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	1	1	1	1	1	2	1	1	1	1	68°F.	70°F.	89	12:00 a.m.

Cutting Test

TABLE A-3

Experiment I — Asparagus - Top Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Place of Experiment	Time From Cutting	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	380	440	440	360	440	65°F.	63°F.	94	6:00 a.m.
Packing Plant	3 hrs.	380	400	440	360	440	71°F.	70°F.	90	9:00 a.m.
After Bunching	5 hrs.	380	480	460	380	460	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	440	480	480	400	460	76°F.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	480	480	480	440	480	68°F.	70°F.	90	10:00 a.m.

It will be noted in Table A-1 that the green color of the asparagus spears was practically without variation indicating that the temperature was sufficiently low to prevent any change in the garden-fresh color of the spears.

The amount of feathering of the asparagus heads remained unchanged from the time of harvest until they were sold on the wholesale market (Table A-2).

Pressure tests which are recorded on Table A-3 showed only a slight increase in the toughness of the asparagus spear during the marketing operation.

Asparagus - Experiment II

In this experiment, the asparagus was bottom iced with 10 lbs. of No. 2 ice. The lowest temperature during the entire marketing operation with this method of icing was 60°F.--much too high a temperature to have any marked effect in slowing down the deterioration process going on in the asparagus (Table B).

In both the experimental crates and the control crate, there was a marked deterioration in the color of the asparagus spears. Changes in color began shortly after harvest in experimental and control crates and progressively grew worse during the market operation (Table B-1).

As in the preceding experiment, the amount of

Temperature

TABLE B

Experiment II Asparagus - Bottom Iced with 10 lbs. of No. 2 Ice July 5-8, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	63°F.	63°F.	63°F.	63°F.	65°F.	63°F.	94	6:00 a.m.
In Field Boxes	2 hrs.	68°F.	68°F.	68°F.	68°F.	70°F.	66°F.	94	8:00 a.m.
In Packing Plant	3 hrs.	72°F.	73°F.	73°F.	72°F.	71°F.	70°F.	90	9:00 a.m.
In Packing Plant	5 hrs.	77°F.	76°F.	76°F.	77°F.	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	73°F.	73°F.	72°F.	78°F.	76°F.	80°F.	65	11:30 a.m.
After Icing	7 hrs.	64°F.	64°F.	64°F.	80°F.	80°F.	85°F.	56	1:00 p.m.
After Icing	8 hrs.	61°F.	61°F.	60°F.	85°F.	82°F.	86°F.	54	2:00 p.m.
Wholesale Market	18 hrs.	76°F.	76°F.	75°F.	84°F.	68°F.	70°F.	89	12:00 a.m.
Wholesale Market	19 hrs.	75°F.	75°F.	76°F.	81°F.	67°F.	70°F.	90	1:00 a.m.
Wholesale Market	20 hrs.	76°F.	76°F.	76°F.	78°F.	66°F.	70°F.	90	2:00 a.m.
Wholesale Market	21 hrs.	76°F.	76°F.	76°F.	78°F.	65°F.	69°F.	90	3:00 a.m.

Color

TABLE B-1

Experiment II — Asparagus - Bottom Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	2	1	1	2	2	1	1	2	65°F.	63°F.	90	12:00 a.m.
In Field Boxes	2 hrs.	1	1	3	2	1	2	2	1	2	2	70°F.	66°F.	94	8:00 a.m.
In Packing Plant	3 hrs.	2	1	3	2	1	2	2	1	2	4	71°F.	70°F.	90	9:00 a.m.
After Bunching	5 hrs.	2	1	3	3	1	2	2	1	2	4	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	2	2	4	3	1	3	3	1	3	4	76°F.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	3	2	4	4	2	3	3	1	4	4	68°F.	70°F.	89	12:00 a.m.

Amount of Feathering

TABLE B-2

Asparagus - Bottom Iced with 10 lbs. of No. 2 Ice — July 5-6, 1950

Harvest Time	0 hrs.	1	1	2	2	1	1	1	1	1	2	65°F.	63°F.	94	8:00 a.m.
After Bunching	3 hrs.	1	1	2	2	1	1	1	1	1	2	71°F.	70°F.	90	9:00 a.m.
After Icing	5 hrs. 30 min.	1	1	2	2	1	1	1	1	1	2	76°F.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	1	1	2	2	1	1	1	1	1	2	68°F.	70°F.	89	12:00 a.m.

Cutting Test

TABLE B-3

Experiment II Asparagus - Bottom Iced with 10 lbs. of No. 2 Ice July 5-6, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	360	440	380	380	400	65°F.	73°F.	99	6:00 a.m.
Packing Plant	3 hrs.	360	440	400	440	400	71°F.	70°F.	90	9:00 a.m.
After Bunching	5 hrs.	440	460	440	400	440	74°F.	79°F.	68	11:00 a.m.
After Icing	5 hrs. 30 min.	420	480	460	420	440	76°R.	80°F.	65	11:30 a.m.
Wholesale Market	18 hrs.	480	480	480	400	460	68°F.	70°F.	90	12:00 a.m.

feathering of the asparagus heads remained unchanged from the time of harvest until they were sold on the wholesale market (Table B-2).

As will be noted in Table B-3, the application of 10 lbs. of ice to the bottom of the asparagus crates had no noticeable effect in keeping the asparagus in a fresh, crisp condition. By the time the asparagus was sold on the wholesale market, they had become soft, limp and tough.

Asparagus - Experiment III

Packing asparagus in 4 ins. of No. 2 ice gave very satisfactory results. The temperature of the asparagus upon arrival at the market averaged 42°F. (Table C, the lowest during the entire operation, and thirteen degrees below the critical temperature of 55°F. as recommended by Platenius (34).

Color of the asparagus was excellent upon reaching the wholesale market. The 4 ins. of ice maintained the fresh green color better than any previous method tested (Table C-1).

The amount of feathering of the asparagus heads remained unchanged from the time of harvest until they were sold on the wholesale market (Table C-2).

Pressure tests (Table C-3) showed asparagus packed in 4 ins. of No. 2 ice were in excellent condition

Temperature

TABLE C

Experiment III — Apparatus - Packed in 4 ins. of No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	72°F.	69°F.	85	7:00 a.m.
In Field Boxes	1 hr.	74°F.	74°F.	74°F.	74°F.	74°F.	72°F.	80	8:00 a.m.
In Packing Plant	2 hrs.	76°F.	75°F.	77°F.	76°F.	78°F.	76°F.	77	9:00 a.m.
In Packing Plant	4 hrs.	79°F.	79°F.	79°F.	79°F.	74°F.	81°F.	59	11:00 a.m.
After Icing	4 hrs. 30 min.	67°F.	67°F.	66°F.	80°F.	74°F.	80°F.	56	11:30 a.m.
After Icing	6 hrs.	52°F.	53°F.	53°F.	81°F.	78°F.	83°F.	53	1:00 p.m.
After Icing	7 hrs.	42°F.	42°F.	41°F.	82°F.	80°F.	82°F.	53	2:00 p.m.
Wholesale Market	17 hrs.	45°F.	46°F.	45°F.	77°F.	65°F.	67°F.	82	12:00 a.m.
Wholesale Market	18 hrs.	46°F.	47°F.	47°F.	74°F.	64°F.	66°F.	83	2:00 a.m.
Wholesale Market	20 hrs.	46°F.	46°F.	47°F.	73°F.	63°F.	66°F.	83	3:00 a.m.

Color

TABLE C-1

Experiment III — Asparagus - Packed in 4 Ins. of No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	2	1	2	2	1	1	1	1	1	72°F.	69°F.	85	7:00 a.m.
In Field Boxes	1 hr.	1	2	1	3	2	1	1	1	1	2	74°F.	72°F.	80	8:00 a.m.
In Packing Plant	2 hrs.	1	2	1	3	2	1	1	1	1	2	78°F.	76°F.	77	9:00 a.m.
After Bunching	4 hrs.	1	3	1	3	2	1	1	1	2	2	74°F.	81°F.	59	11:00 a.m.
After Icing	4 hrs. 30 min.	1	3	1	3	2	1	1	1	2	2	74°F.	82°F.	56	11:30 a.m.
Wholesale Market	17 hrs.	1	3	1	3	2	1	1	1	2	3	65°F.	67°F.	82	12:00 a.m.

Amount of Feathering

TABLE C-2

Asparagus - Packed in 4 Ins. of No. 2 Ice — July 3-4, 1950

Harvest Time	0 hrs.	1	1	1	1	2	1	1	1	1	2	72°F.	69°F.	85	7:00 a.m.
After Bunching	2 hrs.	1	1	1	1	2	1	1	1	1	2	78°F.	76°F.	77	9:00 a.m.
After Icing	6 hrs.	1	1	1	1	2	1	1	1	1	2	78°F.	83°F.	53	1:00 p.m.
Wholesale Market	17 hrs.	1	1	1	1	2	1	1	1	1	2	65°F.	67°F.	82	10:00 a.m.

Cutting Test

TABLE C-3

Experiment III — Asparagus - Packed in 4 Ins. of No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	380	400	360	400	480	72°F.	69°F.	85	7:00 a.m.
Packing Plant	2 hrs.	380	400	400	360	480	78°F.	76°F.	77	9:00 a.m.
After Bunching	4 hrs.	400	400	460	440	480	74°F.	81°F.	59	11:00 a.m.
After Icing	6 hrs.	440	480	480	480	480	78°F.	83°F.	53	1:00 p.m.
Wholesale Market	17 hrs.	440	460	480	480	480	65°F.	67°F.	82	12:00 a.m.

when sold on the wholesale market. The pressure test showed only very slight increases in the amount of toughness of the asparagus from the time of harvest until they were sold on the wholesale market. On the other hand, there was a noted and steady increase in the toughness of the asparagus in the control crate.

Asparagus - Exceriment IV

Asparagus packed in No. 2 ice so that the tips were just showing gave excellent results. The three iced crates of asparagus showed no evidence of any type of deterioration as the temperature was maintained well below the critical temperature of 55°F. during the entire marketing operation (Table D).

This method of icing was found to be one of the most successful of any employed in the two seasons of experimental work from a viewpoint of preserving color. When the iced asparagus in this experiment arrived at the wholesale market, they had retained almost completely their fresh, green asparagus color. In comparison, the asparagus in the control crate had become a dark green and completely lost its garden-fresh color (Table D-1).

As in the preceding experiments, the amount of feathering of the asparagus heads was unaffected. No change in the amount of feathering was discernible from the time of harvest until the asparagus was sold on the

Temperature

TABLE D

Experiment IV Asparagus - Packed in No. 2 Ice so Tips are Just Showing July 29-30, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	55°F.	55°F.	55°F.	55°F.	58°F.	56°F.	86	8:00 a.m.
In Field Boxes	2 hrs.	63°F.	63°F.	63°F.	63°F.	70°F.	68°F.	72	8:00 a.m.
In Packing Plant	3 hrs.	68°F.	69°F.	68°F.	68°F.	73°F.	71°F.	70	9:00 a.m.
In Packing Plant	5 hrs.	73°F.	75°F.	74°F.	75°F.	79°F.	80°F.	57	11:00 a.m.
After Icing	5 hrs. 30 min.	73°F.	73°F.	74°F.	75°F.	83°F.	81°F.	56	11:30 a.m.
After Icing	7 hrs.	50°F.	50°F.	50°F.	81°F.	86°F.	83°F.	49	1:00 p.m.
After Icing	8 hrs.	40°F.	40°F.	41°F.	82°F.	84°F.	80°F.	49	2:00 p.m.
Wholesale Market	18 hrs.	43°F.	42°F.	43°F.	78°F.	68°F.	66°F.	70	12:00 a.m.
Wholesale Market	19 hrs.	44°F.	43°F.	43°F.	75°F.	67°F.	66°F.	72	1:00 a.m.
Wholesale Market	20 hrs.	44°F.	44°F.	43°F.	73°F.	64°F.	65°F.	74	2:00 a.m.
Wholesale	21 hrs.	44°F.	44°F.	44°F.	73°F.	62°F.	65°F.	75	3:00 a.m.

Color

TABLE D-1

Experiment IV Asparagus - Packed in Ice So Tips Are Just Showing June 29-30, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	2	1	1	1	2	2	1	1	58°F.	56°F.	68	6:00 a.m.
In Field Boxes	2 hrs.	1	1	3	1	2	1	2	3	1	1	70°F.	68°F.	72	8:00 a.m.
In Packing Plant	3 hrs.	1	1	3	1	2	1	2	3	1	2	73°F.	71°F.	70	9:00 a.m.
After Bunching	5 hrs.	1	1	3	1	2	1	2	3	1	2	83°F.	81°F.	57	11:00 a.m.
After Icing	7 hrs.	1	1	4	1	2	1	2	4	1	2	86°F.	83°F.	49	1:00 p.m.
Wholesale Market	18 hrs.	1	1	4	1	2	1	2	4	1	2	68°F.	65°F.	70	12:00 a.m.

Amount of Feathering

TABLE D-2

Asparagus - Packed in Ice So Tips are Just Showing June 29-30, 1950

Harvest Time	0 hrs.	1	1	1	1	2	1	1	1	1	2	58°F.	56°F.	86	6:00 a.m.
After Bunching	3 hrs.	1	1	1	1	2	1	1	1	1	2	73°F.	71°F.	70	9:00 a.m.
After Icing	5 hrs. 30 min.	1	1	1	1	2	1	1	1	1	2	83°F.	81°F.	56	11:30 a.m.
Wholesale Market	18 hrs.	1	1	1	1	2	1	1	1	1	2	68°F.	66°F.	70	12:00 a.m.

Cutting Test

TABLE D-3

Experiment IV Asparagus - Packed in Ice So Tips Are Just Showing June 29-30, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	350	440	380	380	400	56°F.	56°F.	86	6:00 a.m.
Packing Plant	3 hrs.	400	440	400	400	350	73°F.	71°F.	70	9:00 a.m.
After Bunching	5 hrs.	440	480	450	440	380	79°F.	80°F.	57	11:00 a.m.
After Icing	7 hrs.	440	400	480	460	440	86°F.	83°F.	49	1:00 p.m.
Wholesale Market	18 hrs.	400	350	460	460	400	68°F.	66°F.	70	12:00 a.m.

wholesale market (Table D-2).

Pressure Test

There was no noticeable decline in the crispness of the spears of asparagus from the time of harvest until they were sold on the wholesale market. This will be very apparent by consulting Table D-3.

Asparagus - Experiment V

Completely packing asperagus in No. 2 ice gave excellent results with no visible type of deterioration present. As recommended by Platenius (34), the temperature of the asparagus was maintained well below the critical temperature of 55°F. and for the most part during the marketing operation in the lower 40's.

Color

Asparagus completely covered with No. 2 ice was found to be one of the best methods of icing as far as the retention of color was concerned. The three experimental boxes of asparagus were just as rich in color at the wholesale market as they were at the time of harvest (Table E-1).

Amount of Feathering

Here again, the amount of feathering of the asparagus heads was unaffected. The amount of feathering of the asparagus heads was unchanged from the time of harvest until they were sold on the wholesale market (Table E-2).

Temperature

TABLE E

Experiment V — Asparagus - Completely Packed in No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	72°F.	69°F.	85	7:00 a.m.
In Field Boxes	1 hr.	74°F.	74°F.	74°F.	74°F.	74°F.	72°F.	80	8:00 a.m.
In Packing Plant	2 hrs.	76°F.	76°F.	76°F.	76°F.	76°F.	76°F.	77	9:00 a.m.
Before Icing	4 hrs.	79°F.	78°F.	78°F.	79°F.	74°F.	81°F.	69	11:00 a.m.
After Icing	4 hrs. 30 min.	56°F.	56°F.	57°F.	79°F.	74°F.	82°F.	56	11:30 a.m.
After Icing	6 hrs.	41°F.	40°F.	41°F.	81°F.	78°F.	83°F.	53	1:00 p.m.
After Icing	7 hrs.	42°F.	41°F.	41°F.	82°F.	80°F.	82°F.	53	2:00 p.m.
Wholesale Market	17 hrs.	43°F.	44°F.	43°F.	77°F.	65°F.	67°F.	82	12:00 a.m.
Wholesale Market	18 hrs.	44°F.	44°F.	43°F.	76°F.	63°F.	67°F.	82	1:00 a.m.
Wholesale Market	19 hrs.	44°F.	45°F.	45°F.	74°F.	64°F.	66°F.	83	2:00 a.m.
Wholesale Market	20 hrs.	44°F.	43°F.	44°F.	73°F.	63°F.	66°F.	83	3:00 a.m.

Color

TABLE E-1

Experiment V — Asparagus - Completely Packed in No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	1	1	1	1	1	1	2	2	72°F.	69°F.	85	7:00 a.m.
In Field Boxes	1 hr.	1	1	1	1	1	1	1	1	2	2	74°F.	72°F.	80	8:00 a.m.
In Packing Plant	2 hrs.	1	1	1	1	1	1	1	1	2	3	78°F.	76°F.	77	9:00 a.m.
After Bunching	4 hrs.	2	1	1	1	1	1	1	1	2	3	74°F.	81°F.	59	11:00 a.m.
After Icing	4 hrs. 30 min.	2	1	1	1	2	2	1	1	2	3	74°F.	82°F.	56	11:30 a.m.
Wholesale Market	17 hrs.	2	1	1	1	2	2	1	1	2	3	65°F.	67°F.	82	12:00 a.m.

Amount of Feathering

TABLE E-2

Experiment V — Asparagus - Completely Packed in No. 2 Ice — July 3-4, 1950

Harvest Time	0 hrs.	1	1	1	1	2	1	1	1	1	2	72°F.	69°F.	85	7:00 a.m.
After Bunching	2 hrs.	1	1	1	1	2	1	1	1	1	2	78°F.	76°F.	77	9:00 a.m.
After Icing	6 hrs.	1	1	1	1	2	1	1	1	1	2	78°F.	83°F.	53	1:00 p.m.
Wholesale Market	17 hrs.	1	1	1	1	2	1	1	1	1	2	65°F.	67°F.	82	12:00 a.m.

Cutting Test

TABLE E-3

Experiment V — Asparagus - Completely Packed in No. 2 Ice — July 3-4, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	400	360	440	400	380	72°F.	69°F.	85	7:00 a.m.
Packing Plant	2 hrs.	400	380	300	480	440	78°F.	76°F.	77	8:00 a.m.
After Bunching	4 hrs.	440	460	400	460	460	74°F.	81°F.	59	11:00 a.m.
After Icing	6 hrs.	480	460	400	460	460	78°F.	83°F.	53	1:00 p.m.
Wholesale Market	17 hrs.	480	460	460	460	480	65°F.	67°F.	82	12:00 a.m.

Pressure Test

There was a very slight increase in the toughness of the asparagus during the market operation with most of it occurring before icing. After icing, the pressure tests remained approximately the same with only slight changes (Table E-3). On the whole, the asparagus used in this experiment was sold on the wholesale market in good garden-fresh, crisp condition.

Asparagus - Experiment VI

It will be noted on Table F that freshening of asparagus in ice water had no effect in lowering the temperature of the asparagus. During the freshening period, the temperature in the experimental crates rose steadily. Also, in Table F, it will be noted that the temperature in the three experimental crates upon arrival and at the wholesale market was higher than the temperature in the control crate.

Upon making observation of the asparagus at the wholesale market, it was found that the asparagus in the crates that had been freshened in ice water were in approximately the same condition as those in the control crate. In the three experimental crates as well as in the control crate, the asparagus had become limp and fibrous, and there was also very serious deterioration in the color of the asparagus spears.

Temperature

TABLE F

Experiment VI — Asparagus - Freshening in Ice Water — June 27-28, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	64°F.	65°F.	79	6:00 a.m.
In Field Boxes	1 hr.	64°F.	64°F.	64°F.	64°F.	65°F.	68°F.	79	7:00 a.m.
In Packing Plant	4 hrs.	67°F.	67°F.	67°F.	67°F.	77°F.	71°F.	68	10:00 a.m.
After Bunching	4 hrs. 30 min.	71°F.	71°F.	72°F.	73°F.	77°F.	78°F.	68	10:30 a.m.
Freshening Begins	6 hrs. 30 min.	75°F.	76°F.	72°F.	76°F.	83°F.	79°F.	65	12:30 a.m.
During Freshening	6 hrs. 45 min.	75°F.	76°F.	74°F.	76°F.	83°F.	79°F.	65	12:45 a.m.
During Freshening	7 hrs.	75°F.	76°F.	74°F.	77°F.	84°F.	80°F.	65	1:00 p.m.
During Freshening	7 hrs. 15 min.	76°F.	76°F.	74°F.	77°F.	85°F.	81°F.	65	1:15 p.m.
During Freshening	7 hrs. 30 min.	75°F.	76°F.	74°F.	76°F.	84°F.	82°F.	65	1:30 p.m.
Wholesale Market	19 hrs. 30 min.	69°F.	70°F.	71°F.	66°F.	61°F.	68°F.	66	1:30 a.m.
Wholesale Market	20 hrs. 30 min.	68°F.	69°F.	69°F.	66°F.	60°F.	66°F.	72	2:30 a.m.
Wholesale Market	21 hrs. 30 min.	68°F.	68°F.	67°F.	65°F.	57°F.	65°F.	73	3:30 a.m.

Color

TABLE F-1

Experiment VI — Asparagus - Freshening in Ice Water — June 27-28, 1950

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	1	1	1	1	1	1	1	1	65°F.	64°F.	79	6:00 a.m.
In Field Box	1 hr.	2	1	1	1	1	3	1	1	1	1	66°F.	65°F.	79	7:00 a.m.
In Packing Plant	4 hrs.	2	1	2	1	2	3	1	1	1	1	71°F.	77°F.	68	10:00 a.m.
After Bunching	4 hrs. 30 min.	2	1	2	1	2	4	1	1	1	2	78°F.	77°F.	68	10:30 a.m.
After Freshening	7 hrs. 30 min.	3	1	2	1	2	4	1	1	1	2	82°F.	84°F.	65	1:30 p.m.
Wholesale Market	19 hrs. 30 min.	3	2	2	1	3	4	1	1	1	3	68°F.	61°F.	66	1:30 a.m.

Amount of Feathering

TABLE F-2

Asparagus - Freshening in Ice Water — June 27-28, 1950

Harvest Time	0 hrs.	1	1	2	3	1	3	3	1	2	2	65°F.	64°F.	79	6:00 a.m.
After Bunching	4 hrs. 30 min.	1	1	2	3	1	3	3	1	2	2	71°F.	77°F.	68	10:30 a.m.
After Freshening	7 hrs. 30 min.	1	1	2	3	1	3	3	1	2	3	82°F.	84°F.	65	1:30 p.m.
Wholesale Market	19 hrs.	1	1	2	3	1	3	3	1	2	3	68°F.	61°F.	66	1:30 a.m.

Cutting Test

TABLE F-3

Experiment VI — Asparagus - Freshening in Ice Water — June 27-28, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	480	400	430	440	440	65°F.	64°F.	79	6:00 a.m.
Packing Plant	4 hrs.	480	400	400	420	400	71°F.	77°F.	68	10:00 a.m.
After Bunching	4 hrs. 30 min.	450	360	380	400	340	78°F.	77°F.	68	10:30 a.m.
After Freshening	7 hrs. 30 min.	400	360	340	360	340	82°F.	84°F.	65	1:30 p.m.
Wholesale Market	19 hrs. 30 min.	400	320	300	300	340	63°F.	61°F.	66	1:30 a.m.
Wholesale Market	21 hrs. 30 min.	380	300	300	300	320	65°F.	57°F.	73	3:30 a.m.

Color

Freshening of asparagus in ice water had no great effect on preserving the fresh green color of the asparagus spears. There was a steady decline in color all during the marketing operation. The deterioration was particularly rapid during the last four hours of the marketing process (Table F-1).

Amount of Feathering

The amount of feathering remained unaffected by freshening in ice water. The amount of feathering of the asparagus heads remained unchanged from the time of harvest until they were sold on the wholesale market (Table F-2).

Pressure Test

The pressure tests showed a very steady increase in the toughness of the asparagus as the marketing operation progressed, and by the time the asparagus was sold on the wholesale market, the spears had become limp and fibrous (Table F-3).

Asparagus - Experiment VII

It will be noted on Table G that the immersion of the asparagus in a hydrocooler for fifteen minutes had an immediate effect in lowering the temperature; however, the effect was not a lasting one.

Hydrocooling of asparagus caused an immediate

lowering of the temperature from 81°F. to 47°F. From the time the asparagus was removed from the hydrocooler and the above temperatures recorded, there was a steady increase in the temperature until they arrived at the wholesale market thirteen hours from the time of hydrocooling. By that time, the temperature in the three experimental crates had reached that of the temperature in the control crate.

Color

Immersion hydrocooling had very little lasting effects on the color retention of the asparagus spears. Immediately after hydrocooling, the color had improved but began to deteriorate within an hour (Table G-1).

Amount of Feathering

As in all the preceding experiments, the amount of feathering of the asparagus heads was unaffected. The amount of feathering of the asparagus heads was unchanged from the time of harvest until they were sold on the wholesale market (Table G-2).

Pressure Test

There was a noticeable and steady increase in the pressure required to cut through a spear from the time of harvest until the asparagus was sold on the wholesale market (Table G-3).

Temperature

TABLE C

Experiment VII — Asparagus - Hydrocooled for 15 Minutes — June 12-13, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	65°F.	65°F.	65°F.	65°F.	86°F.	64°F.	90	7:00 a.m.
In Field Boxes	1 hr.	71°F.	71°F.	71°F.	71°F.	68°F.	59°F.	80	8:00 a.m.
In Field Boxes	2 hrs.	77°F.	77°F.	77°F.	77°F.	83°F.	63°F.	68	9:00 a.m.
In Packing Plant	3 hrs.	79°F.	79°F.	79°F.	79°F.	80°F.	65°F.	84	10:00 a.m.
In Packing Plant	4 hrs.	80°F.	80°F.	81°F.	80°F.	87°F.	70°F.	61	11:00 a.m.
Hydrocooling Begins	4 hrs. 30 mins.	81°F.	81°F.	81°F.	81°F.	74°F.	70°F.	61	11:30 a.m.
Hydrocooling Ends	4 hrs. 45 min.	47°F.	47°F.	47°F.	81°F.	74°F.	70°F.	60	11:45 a.m.
In Packing Plant	5 hrs.	47°F.	47°F.	47°F.	80°F.	77°F.	71°F.	60	12:00 p.m.
In Packing Plant	6 hrs.	50°F.	50°F.	50°F.	80°F.	78°F.	74°F.	57	1:00 p.m.
Wholesale Market	18 hrs.	77°F.	78°F.	78°F.	76°F.	64°F.	55°F.	91	1:00 a.m.
Wholesale Market	19 hrs.	77°F.	76°F.	76°F.	75°F.	56°F.	53°F.	92	2:00 a.m.
Wholesale Market	21 hrs.	75°F.	74°F.	75°F.	71°F.	52°F.	51°F.	86	4:00 a.m.

Color

TABLE G-1

Experiment VII — Asparagus - Hydrocooler for 15 Minutes — June 12-13, 1951

Place of Experiment	Time From Harvest	A	F	C	D	E	Controls I	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	1	1	1	1	1	2	2	1	66°F.	54°F.	90	7:00 a.m.
In Field Boxes	2 hrs.	1	1	1	1	1	2	1	2	2	1	83°F.	63°F.	68	9:00 a.m.
In Packing Plant	3 hrs.	1	1	1	1	1	2	1	2	2	2	80°F.	66°F.	64	10:00 a.m.
After Bunching	4 hrs.	1	1	1	1	1	2	1	2	2	2	67°F.	70°F.	61	11:00 a.m.
After Soaking	4 hrs. 45 min.	1	1	1	1	1	2	1	2	2	2	74°F.	70°F.	60	11:45 a.m.
Wholesale Market	18 hrs.	1	2	1	1	1	3	1	2	3	4	64°F.	55°F.	91	1:00 a.m.

Amount of Feathering

TABLE G-2

Asparagus - Hydrocooler for 15 Minutes — June 12-13, 1951

Harvest Time	0 hrs.	1	1	1	1	1	3	1	1	2	1	65°F.	54°F.	90	7:00 a.m.
After Bunching	4 hrs.	1	1	1	1	1	3	1	1	2	1	67°F.	70°F.	61	11:00 a.m.
After Soaking	5 hrs.	1	1	1	1	1	3	1	1	2	1	77°F.	71°F.	60	12:00 p.m.
Wholesale Market	18 hrs.	1	1	1	1	1	3	1	1	2	1	64°F.	55°F.	91	1:00 a.m.

Cutting Test

TABLE G-3

Experiment VII — Asparagus - Hydrocooler for 15 Minutes — June 12-13, 1950

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	410	420	400	420	440	66°F.	54°F.	90	7:00 a.m.
Packing Plant	3 hrs.	440	400	420	440	480	80°F.	68°F.	64	10:00 a.m.
After Bunching	4 hrs.	440	450	450	460	480	67°F.	70°F.	61	11:00 a.m.
After Soaking	4 hrs. 45 min.	460	460	450	460		64°F.	70°F.	60	11:45 a.m.
Wholesale Market	21 hrs.	460	490	450	460		52°F.	51°F.	86	4:00 a.m.

Hydrocooling seemed to have little or no effect on preventing the asparagus spears from becoming tough and stringy.

Asparagus - Experiment VIII

It will be noted on Table H that the combination of hydrocooling and icing very effectively maintained a low temperature during the marketing operation. This was in direct contrast to the preceding experiment where only hydrocooling was used.

All the ice had completely melted by the time the produce had reached the wholesale market, yet the asparagus was still cool. The asparagus in the three experimental crates was in excellent condition showing no evidence of any type of deterioration. In the control crate, however, the asparagus had become limp and fibrous, and there was a fading in the green color of the asparagus spears.

Color

Hydrocooling and icing proved to be one of the most effective methods employed in two seasons of work for preserving the green fresh asparagus color.

When the asparagus was sold on the wholesale market, the color was the same as it was at the time of harvest (Table H).

Amount of Feathering

The amount of feathering of the asparagus

Temperature

TABLE H

Experiment VIII — Asparagus - Hydrocooled for 15 Minutes and Top Iced with 10 lbs. of No. 2 Ice — June 25-26, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	74°F.	72°F.	90	7:00 a.m.
In Field Boxes	1 hr.	76°F.	76°F.	76°F.	76°F.	79°F.	76°F.	90	8:00 a.m.
In Field Boxes	2 hrs.	78°F.	78°F.	78°F.	78°F.	79°F.	76°F.	72	9:00 a.m.
In Packing Plant	3 hrs.	78°F.	78°F.	79°F.	78°F.	81°F.	78°F.	66	10:00 a.m.
Soaking Begins	4 hrs.	79°F.	79°F.	80°F.	79°F.	82°F.	79°F.	62	11:00 a.m.
Soaking Ends	4 hrs. 15 min.	51°F.	51°F.	52°F.	79°F.	83°F.	79°F.	62	11:15 a.m.
Icing Begins	4 hrs. 30 min.	51°F.	51°F.	52°F.	80°F.	85°F.	80°F.	62	11:30 a.m.
After Icing	5 hrs.	45°F.	45°F.	45°F.	80°F.	85°F.	80°F.	62	12:00 p.m.
After Icing	6 hrs.	41°F.	41°F.	41°F.	81°F.	84°F.	82°F.	57	1:00 p.m.
Wholesale Market	18 hrs.	46°F.	46°F.	46°F.	75°F.	67°F.	58°F.	82	1:00 a.m.
Wholesale Market	19 hrs.	47°F.	47°F.	48°F.	74°F.	66°F.	56°F.	82	2:00 a.m.
Wholesale Market	21 hrs.	50°F.	50°F.	50°F.	73°F.	63°F.	52°F.	86	4:00 a.m.

Color

TABLE H-1

Experiment VIII — Asparagus - Hydrocooler for 15 Minutes and Iced with 10 lbs. of No. 2 Ice — June 15-16, 1951

Place of Experiment	Time From Harvest	Controls A	B	C	D	E	F	G	H	I	J	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	1	1	1	1	1	1	1	2	1	2	74°F.	72°F.	90	7:00 a.m.
In Field Boxes	2 hrs.	1	1	1	1	1	2	1	2	1	2	79°F.	76°F.	72	9:00 a.m.
In Packing Plant	3 hrs.	1	1	1	1	1	3	1	2	1	3	81°F.	78°F.	66	10:00 a.m.
After Bunching	4 hrs.	1	2	1	1	1	3	1	2	1	3	82°F.	79°F.	62	11:00 a.m.
After Soaking and Icing	6 hrs.	1	2	1	1	1	3	1	2	1	3	88°F.	82°F.	67	1:00 p.m.
Wholesale Market	18 hrs.	1	2	1	1	1	3	1	2	1	3	67°F.	59°F.	82	1:00 a.m.

Amount of Feathering

TABLE H-2

Asparagus - Hydrocooler for 15 Minutes and Iced with 10 lbs. of No. 2 Ice — June 15-16, 1951

Harvest Time	0 hrs.	1	1	1	1	2	1	1	1	2	1	74°F.	72°F.	90	7:00 a.m.
After Bunching	3 hrs.	1	1	1	1	2	1	1	1	2	1	81°F.	78°F.	66	10:00 a.m.
After Icing	6 hrs.	1	1	1	1	2	1	1	1	2	1	88°F.	82°F.	57	1:00 p.m.
Wholesale	18 hrs.	1	1	1	1	2	1	1	1	2	1	67°F.	59°F.	82	1:00 a.m.

Cutting Test

TABLE H-3

Experiment VIII — Asparagus - Hydrocooler for 15 Minutes and Top Iced with 10 lbs. of No. 2 Ice — June 15-16, 1951

Place of Experiment	Time From Harvest	A	B	C	D	Control E	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	400	420	400	380	400	74°F.	72°F.	90	7:00 a.m.
Packing Plant	3 hrs.	410	430	440	400	420	81°F.	78°F.	66	10:00 a.m.
After Bunching	4 hrs.	440	460	440	420	440	82°F.	79°F.	62	11:00 a.m.
After Soaking and Icing	6 hrs.	440	460	430	420	440	88°F.	82°F.	57	1:00 p.m.
Wholesale Market	18 hrs.	440	460	430	420	440	67°F.	57°F.	82	1:00 a.m.

heads was unaffected by this method as by the preceding methods. The amount of feathering of the asparagus heads was unchanged from the time of harvest until they were sold on the wholesale market (Table H-2).

Pressure Test

Combinations of hydrocooling and icing proved very effective in preventing the asparagus spears from becoming tough. As a matter of fact, when the asparagus spears were sold on the wholesale market, they were in as good a condition as when harvested (Table H-3).

Lettuce

Lettuce was iced and/or hydrocooled during the seasons of 1950 and 1951 in the packing shed at William Richards' farm in Forestdale, Massachusetts. The same evening of icing and hydrocooling, the lettuce was transported by truck to the First National Warehouse in Somerville, Massachusetts. These experiments were conducted over a period of from twenty-two to twenty-four hours.

Methods of Packing, Icing and Hydrocooling

Lettuce was harvested between 10:00 and 12:00 a.m. Heads were graded, trimmed and packed into boxes right in the field; eighteen heads packed in each box in two layers, nine to each layer. Four boxes of lettuce

were used in each experiment--three for experimental purposes and one as a control.

History of Produce

Lettuce was iced and/or hydrocooled between 11:00 a.m. and 12 noon. At approximately 7:00 p.m. the same evening, the lettuce was transported to the warehouse arriving in Somerville at approximately 9:00 p.m. The following morning, they were distributed to the retail stores.

Lettuce - Experiment I

On the whole, top icing the lettuce with 20 lbs. of No. 1 ice produced satisfactory results with the temperature of the lettuce after icing being maintained in the upper 40's and lower 50's (Table I).

Although the temperature in the experimental boxes was held within a protective range after icing, the butts still showed browning. These results indicate the necessity of some type of paper liner to protect the produce from the air.

Lettuce - Experiment II

In this experiment, the lettuce was iced in the center of the pack with 20 lbs. of No. 1 ice. The results of this method of icing were satisfactory with the temperature (Table J) in all three of the experimental boxes, as recommended by Platenius (34), being held below

Temperature

TABLE I

Experiment I — Lettuce - Top Iced with 20 lbs. of No. 1 ice — August 3-4, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	75°F.	75°F.	75°F.	75°F.	76°F.	72°F.	79	10:00 a.m.
In Truck In Field	1 hr.	78°F.	77°F.	78°F.	77°F.	80°F.	72°F.	79	11:00 a.m.
Before Icing	2 hrs.	80°F.	81°F.	81°F.	81°F.	78°F.	72°F.	79	12:00 p.m.
After Icing	2 hrs. 30 min.	75°F.	75°F.	76°F.	81°F.	78°F.	73°F.	79	12:30 p.m.
In Wholesale Warehouse	11 hrs.	49°F.	49°F.	49°F.	78°F.	70°F.	62°F.	90	9:00 p.m.
Retail Store	22 hrs.	52°F.	51°F.	51°F.	76°F.	74°F.	62°F.	81	9:00 a.m.

Temperature

TABLE J

Experiment II Lettuce - Center Iced with 20 lbs. of No. 1 Ice August 28-29, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	72°F.	72°F.	72°F.	72°F.	76°F.	74°F.	82	9:00 a.m.
In Truck In Field	1 hr.	72°F.	72°F.	72°F.	72°F.	81°F.	77°F.	80	10:00 a.m.
In Packing Plant	2 hrs. 30 min.	73°F.	73°F.	74°F.	73°F.	78°F.	81°F.	73	11:30 a.m.
In Packing Plant	3 hrs.	73°F.	73°F.	72°F.	73°F.	75°F.	82°F.	72	12:00 p.m.
Before Icing	4 hrs.	74°F.	74°F.	74°F.	74°F.	76°F.	83°F.	72	1:00 p.m.
Warehouse	9 hrs.	46°F.	47°F.	44°F.	75°F.	80°F.	81°F.	76	6:00 p.m.
Retail Store	23 hrs.	54°F.	50°F.	51°F.	77°F.	77°F.	73°F.	94	8:00 a.m.

the critical temperature of 55°F. until they arrived at the retail store.

By the time the lettuce had reached the retail store, the upper layers of lettuce showed severe browning of the butts, and the lower outer leaves of the heads had become bruised while the bottom layers of lettuce were in excellent condition showing no browning or bruising.

In the control box, the high temperatures throughout the marketing operation had caused browning of the lettuce butts and outer leaves in all heads, and the lettuce in the control box was quite wilted.

Lettuce - Experiment III

Bottom icing the lettuce with 20 lbs. of No. 2 ice proved unsatisfactory. Using this method of icing, it was found impossible to maintain a low temperature during the market operation. The lowest temperature accomplished during the entire operation after icing was 73°F. (Table K)--much too high a temperature to prevent or even retard the deterioration process going on in the lettuce.

Upon the arrival of the lettuce at the retail store, the butts of the lettuce in both layers in all three boxes were very badly browned, and the outer leaves of all heads had become browned and bruised.

TABLE V

Temperature

Experiment III Lettuce - Bottom Iced with 20 lbs. of No. 1 Ice August 28-29, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	72°F.	72°F.	72°F.	72°F.	75°F.	74°F.	82	9:00 a.m.
In Truck In Field	1 hr.	72°F.	73°F.	73°F.	72°F.	81°F.	77°F.	80	10:00 a.m.
In Packing Plant	2 hrs. 30 min.	73°F.	73°F.	73°F.	74°F.	78°F.	81°F.	72	11:30 a.m.
In Packing Plant	3 hrs.	73°F.	73°F.	73°F.	74°F.	75°F.	82°F.	72	12:00 p.m.
Warehouse	4 hrs.	74°F.	73°F.	73°F.	74°F.	76°F.	82°F.	72	1:00 p.m.
Retail Store	23 hrs.	69°F.	67°F.	71°F.	72°F.	77°F.	73°F.	94	8:00 a.m.

The lettuce in the bottom layers of all three experimental boxes were badly pitted due to the pressure of the upper layers of lettuce forcing the lower layer upon the crushed ice.

In the control box, the exceptionally high temperatures throughout the marketing operation caused severe browning of the butts and outer leaves on all heads. Also, the heads of the lettuce were wilted.

Lettuce - Experiment IV

Top and center icing of the lettuce boxes with 10 lbs. of No. 1 ice proved very satisfactory with the temperature being maintained throughout the marketing operation well below the critical temperature of 55°F., as recommended by Platenius (34).

When the lettuce arrived at the retail store, the butts of the top layers of lettuce were slightly browned. In the control box, the high temperatures had caused browning of the butts and outer leaves in all heads, and the lettuce in the control box was quite wilted.

It will be noted in Table L that the temperature in the iced boxes of lettuce was kept well within the protective temperature range recommended by Platenius (34). This would indicate that it was the oxidation effect caused by exposure of the lettuce to the air that was responsible for the browning of the butts and not the high temperature.

TABLE L

Temperatures

Experiment IV — Lettuce - Top and Center Each Iced with 10 lbs. of No. 1 Ice — August 24-25, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	70°F.	66°F.	93	9:00 a.m.
Packing Plant	1 hr.	71°F.	71°F.	71°F.	72°F.	79°F.	70°F.	90	10:00 a.m.
In Packing Plant	2 hrs. 30 min.	72°F.	72°F.	72°F.	72°F.	72°F.	77°F.	80	11:30 a.m.
Before Icing	4 hrs.	72°F.	73°F.	73°F.	74°F.	74°F.	83°F.	60	1:00 p.m.
Warehouse	9 hrs.	43°F.	44°F.	40°F.	75°F.	85°F.	82°F.	67	6:00 p.m.
Retail Stores	23 hrs.	48°F.	48°F.	48°F.	73°F.	71°F.	68°F.	92	8:00 a.m.

Lettuce - Experiment V

It will be noted on Table M that icing the lettuce with 10 lbs. of No. 1 ice on the top and bottom of the boxes produced satisfactory results as far as maintaining a low temperature was concerned.

Upon the arrival of the lettuce at the retail store, the ice in all three of the experimental box had completely melted, and the temperature had begun to rise (Table M). Only the butts and lower outer basel leaves in the upper layers were slightly browned.

The lettuce in the bottom layers of the experimental boxes was badly pitted due to the pressure of the upper layers forcing the lower layers upon the crushed ice. This observation is substantiated by the findings of Lewis (20). This worker maintains that small sizes of ice should be used in vegetable packages. He adds that large chunks of ice and even smaller sizes might cut or bruise commodities when any pressure is applied. In the control box, all heads showed browning of the butts and lower outer leaves, and all heads had wilted.

Lettuce - Experiment VI

Center and bottom icing of the boxes of lettuce with 10 lbs. of No. 1 ice proved fairly satisfactory. The temperature in the experimental boxes was maintained below the critical temperature of 55°F. after icing for

TABLE M

Temperatures

Experiment V — Lettuce - Top and Bottom Each Iced with 10 lbs. of No. 1 Ice — August 8-9, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	68°F.	68°F.	68°F.	68°F.	65°F.	61°F.	88	10:00 A.M.
In Truck In Field	1 hr.	74°F.	74°F.	74°F.	74°F.	69°F.	64°F.	88	11:00 A.M.
Before Icing	2 hrs.	78°F.	78°F.	74°F.	79°F.	69°F.	65°F.	88	12:00 p.m.
After Icing	2 hrs. 30 min.	76°F.	75°F.	75°F.	78°F.	66°F.	61°F.	82	12:30 p.m.
After Icing	3 hrs.	68°F.	69°F.	69°F.	70°F.	67°F.	66°F.	88	1:00 P.M.
Warehouse	11 hrs.	46°F.	47°F.	46°F.	76°F.	71°F.	61°F.	85	9:00 P.M.
Retail Store	22 hrs.	48°F.	49°F.	48°F.	77°F.	72°F.	66°F.	81	8:00 A.M.

TABLE N

Temperature

Experiment VI — Lettuce - Center and Bottom Each Iced with 10 lbs. of No. 1 Ice — August 24-25, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Ice Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	75°F.	66°F.	93	9:00 a.m.
In Packing Plant	1 hr.	72°F.	72°F.	72°F.	72°F.	79°F.	70°F.	90	10:00 a.m.
In Packing Plant	2 hrs. 30 min.	73°F.	73°F.	72°F.	73°F.	72°F.	77°F.	80	11:30 a.m.
In Packing Plant	3 hrs.	73°F.	73°F.	74°F.	73°F.	72°F.	80°F.	72	12:00 p.m.
Before Icing	4 hrs.	74°F.	74°F.	74°F.	73°F.	74°F.	83°F.	60	1:00 p.m.
Warehouse	9 hrs.	49°F.	48°F.	50°F.	75°F.	85°F.	82°F.	67	6:00 p.m.
Retail Store	23 hrs.	50°F.	49°F.	51°F.	73°F.	71°F.	65°F.	92	8:00 a.m.

the remainder of the marketing operation (Table N).

At the retail store, it was noted that there was severe browning of the butts and lower outer leaves of the lettuce in the top layers. There was no evidence of browning in the bottom layers of lettuce in any of the experimental boxes. This browning of the lettuce in the top layers of all the experimental boxes was caused by not using a paper liner in combination with top icing. The upper layers of lettuce were exposed to the air thus accelerating browning.

In the three experimental boxes, there was also pitting of the lettuce leaves in the bottom layers. This was due to the ice in the bottom of the boxes and the pressure of the top layers of lettuce forcing the bottom layers against the ice in the bottom of the box.

In the control box, the butts and outer leaves of all heads were severely browned, and all the lettuce had become wilted.

Lettuce - Experiment VII

It will be noted on Table O that top icing with 20 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner gave excellent results, both from the standpoint of maintaining a low temperature and preventing deterioration during the marketing operation.

Upon the arrival of the lettuce at the retail

TABLE O

Temperature

Experiment VII — Lettuce - Top Iced with 20 lbs. of No. 1 Ice — August 23-24, 1950
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	67°F.	67°F.	67°F.	67°F.	76°F.	68°F.	82	9:15 a.m.
In Packing Plant	1 hr.	68°F.	69°F.	69°F.	68°F.	68°F.	74°F.	78	10:15 a.m.
In Packing Plant	2 hrs.	69°F.	69°F.	69°F.	68°F.	72°F.	77°F.	65	11:15 a.m.
In Packing Plant	2 hrs. 15 min.	69°F.	69°F.	70°F.	69°F.	72°F.	78°F.	64	11:30 a.m.
Before Icing	4 hrs.	71°F.	71°F.	72°F.	71°F.	73°F.	80°F.	62	1:15 p.m.
Warehouse	11 hrs. 15 min.	47°F.	45°F.	45°F.	71°F.	74°F.	72°F.	82	8:30 p.m.
Retail Store	22 hrs. 45 min.	47°F.	45°F.	47°F.	72°F.	68°F.	63°F.	93	8:00 [illegible]

store, all three of the experimental boxes showed absolutely no signs of browning or any other form of deterioration. In the control box, on the other hand, the butts and lower outer leaves of the lettuce showed very definite browning with some of the outer leaves of the lettuce heads in the control box showing wilting.

Lettuce - Experiment VIII

Center icing the lettuce pack with 20 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner gave excellent results both from the standpoint of maintaining a low temperature and preventing deterioration.

The temperature after icing was held in the lower 40's (Table P) for the remainder of the marketing operation. The low temperature and the single paper liner used to cut down air circulation resulted in the lettuce arriving at the retail store in perfect condition; however, in the control box, there was considerable browning of the lower outer leaves and the butts of all the heads of lettuce. There was also wilting of the outer leaves in all heads of lettuce.

Lettuce - Experiment IX

Using a single paper liner and bottom icing, the lettuce boxes with 20 lbs. of No. 1 ice gave just passing results from a standpoint of temperature (Table Q).

TABLE F

Temperature

Experiment VIII Lettuce - Center Iced with 20 lbs. of No. 1 Ice August 21-22, 1930
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Air Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	65°F.	65°F.	65°F.	65°F.	67°F.	63°F.	63	9:00 a.m.
In Packing Plant	1 hr.	68°F.	67°F.	68°F.	68°F.	73°F.	63°F.	69	10:00 a.m.
In Packing Plant	2 hrs.	68°F.	68°F.	68°F.	68°F.	68°F.	69°F.	66	11:00 a.m.
In Packing Plant	3 hrs.	69°F.	69°F.	68°F.	68°F.	67°F.	71°F.	64	12:00 p.m.
Before Loing	4 hrs.	70°F.	70°F.	69°F.	69°F.	70°F.	71°F.	60	1:00 p.m.
Warehouse	12 hrs.	41°F.	43°F.	41°F.	71°F.	70°F.	60°F.	82	9:00 p.m.
Retail Store	23 hrs.	44°F.	44°F.	45°F.	72°F.	72°F.	62°F.	80	8:00 a.m.

This method of icing did maintain the temperature below that of the critical temperature of 55°F. as recommended by Platenius (34), but only by two degrees. The fact that the temperature was still not low enough to prevent deterioration of the lettuce will be evidenced from the description of the produce when it reached the retail store.

When the lettuce arrived at the retail store, the ice had completely melted in all three of the experimental boxes, and the butts in the upper layers of each box showed moderate amounts of browning. On the other hand, in the control box, the butts and lower outer leaves of the lettuce heads were severely browned and pitted. The lower layers of lettuce in all three iced boxes were badly pitted and bruised due to the pressure exerted by the lettuce in the upper layers forcing the heads in the lower layers down upon the sharp, pointed ice.

It is noteworthy that the temperature of the control crate fluctuated during the marketing operation and for the most part was above the atmospheric temperature. This indicates that lettuce does evolve appreciable quantities of heat. This observation is substantiated by the findings of Rose et. al. (38). These workers noted that lettuce evolved 45,980 B. t. u. per ton in twenty-four hours when stored at a temperature of 60°F.

TABLE Q

Temperature

Experiment IX — Lettuce - Bottom Iced with 20 lbs. of No. 1 Ice — August 2-3, 1951
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	76°F.	76°F.	76°F.	76°F.	77°F.	72°F.	59	10:00 a.m.
In Truck In Field	1 hr.	78°F.	78°F.	78°F.	78°F.	79°F.	75°F.	55	11:00 a.m.
Before Icing	2 hrs.	81°F.	82°F.	83°F.	81°F.	79°F.	76°F.	52	12:00 p.m.
After Icing	2 hrs. 30 min.	80°F.	82°F.	81°F.	84°F.	78°F.	77°F.	51	12:30 p.m.
After Icing	3 hrs.	76°F.	77°F.	76°F.	82°F.	78°F.	77°F.	50	1:00 p.m.
Wholesale Market	11 hrs.	52°F.	53°F.	52°F.	78°F.	71°F.	66°F.	72	9:00 p.m.
Retail Store	22 hrs.	55°F.	53°F.	55°F.	75°F.	78°F.	66°F.	81	8:00 a.m.

Lettuce - Experiment X

It will be noted on Table R that the method employed in this experiment of top and center icing the lettuce boxes with 10 lbs. of No. 1 ice and then enclosing the entire pack in a single paper liner produced the most satisfactory results of any method using ice and a paper liner.

The temperature of the experimental boxes was maintained in the upper 30's and lower 40's after icing during the marketing operation (Table R).

By the time the lettuce reached the retail store, the ice had completely melted in the experimental boxes but the lettuce was in perfect condition with no evidence of any deterioration. In the control, butts and lower outer leaves of all heads showed very severe browning, and there was also wilting of the outer leaves on some of the heads.

Lettuce - Experiment XI

The application of 10 lbs. of No. 1 ice to the top and bottom of the lettuce pack and its enclosure in a single paper liner gave satisfactory results from a standpoint of maintaining a low temperature during the marketing operation. The highest temperature recorded in the experimental boxes after icing was 48°F. (Table S), seven degrees below the critical temperature of 55°F. as

TABLE R

Temperature

Experiment X — Lettuce - Top and Center Each Iced with 10 lbs. August 23-24, 1950 of No. 1 Ice - Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	67°F.	67°F.	67°F.	67°F.	76°F.	68°F.	82	9:15 a.m.
In Packing Plant	1 hr.	68°F.	68°F.	69°F.	68°F.	86°F.	74°F.	76	10:15 a.m.
In Packing Plant	2 hrs.	70°F.	70°F.	71°F.	69°F.	72°F.	77°F.	65	11:15 a.m.
In Packing Plant	2 hrs. 15 min.	70°F.	70°F.	71°F.	69°F.	72°F.	78°F.	64	11:30 a.m.
Before Icing	4 hrs.	71°F.	71°F.	71°F.	70°F.	73°F.	80°F.	62	1:15 p.m.
Warehouse	11 hrs. 15 min.	38°F.	38°F.	37°F.	71°F.	74°F.	72°F.	82	8:30 p.m.
Retail Store	22 hrs. 45 min.	40°F.	40°F.	42°F.	72°F.	68°F.	63°F.	93	8:00 p.m.

TABLE 8

Temperature

Experiment XI Lettuce - Top and Bottom Each Iced with 10 lbs. of No. 1 Ice - Single Paper Liner July 25-26, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	80°F.	80°F.	80°F.	80°F.	80°F.	77°F.	70	10:00 a.m.
In Truck In Field	1 hr.	82°F.	82°F.	83°F.	82°F.	86°F.	81°F.	58	11:00 a.m.
Before Icing	2 hrs.	84°F.	84°F.	84°F.	84°F.	82°F.	84°F.	55	12:00 p.m.
After Icing	2 hrs. 30 min.	83°F.	82°F.	83°F.	84°F.	76°F.	84°F.	54	12:30 p.m.
After Icing	3 hrs.	76°F.	76°F.	76°F.	83°F.	76°F.	86°F.	53	1:00 p.m.
Wholesale Warehouse	11 hrs.	44°F.	45°F.	46°F.	81°F.	78°F.	72°F.	68	9:00 p.m.
Retail Store	62 hrs.	47°F.	48°F.	47°F.	80°F.	76°F.	70°F.	78	8:00 a.m.

recommended by Platenius (34).

When the lettuce reached the retail store the following morning, they were in excellent condition with the exception of small pit marks on the bottom layers of lettuce. This pitting was caused by the pressure of the upper layers of lettuce forcing the bottom layers down upon the jagged pieces of ice in the bottom of the box. In the control box, by contrast, the lettuce was severely browned on the butts and lower outer leaves.

Lettuce - Experiment XII

It will be noted on Table T that the application of 10 lbs. of No. 1 ice to the center and bottom of the lettuce boxes and its enclosure in a single paper liner produced satisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration.

When the lettuce arrived at the retail store, all iced boxes of lettuce were in excellent condition with no evidence of any type of deterioration present with the exception of the lettuce in the bottom layers of all three experimental boxes. These were badly pitted due to the pressure of the upper layers of lettuce forcing the lower layers upon the crushed ice.

In the control box, the butts and lower outer leaves had become severely browned and bruised. In all the experiments using ice in reasonable amounts and a

TABLE 7

Temperature

Experiment XII Lettuce - Center and Bottom Each Iced with 10 lbs. August 21-22, 1950
of No. 1 Ice - Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Ass. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	65°F.	65°F.	65°F.	65°F.	67°F.	63°F.	88	9:00 a.m.
In Packing Plant	1 hr.	68°F.	67°F.	67°F.	67°F.	73°F.	66°F.	68	10:00 a.m.
In Packing Plant	2 hrs.	68°F.	68°F.	68°F.	68°F.	66°F.	69°F.	66	11:00 a.m.
In Packing Plant	3 hrs.	69°F.	69°F.	68°F.	69°F.	67°F.	71°F.	64	12:00 p.m.
Before Icing	4 hrs.	69°F.	69°F.	70°F.	70°F.	70°F.	74°F.	60	1:00 p.m.
Warehouse	12 hrs.	42°F.	43°F.	43°F.	71°F.	70°F.	60°F.	82	9:00 p.m.
Retail Store	23 hrs.	46°F.	45°F.	47°F.	72°F.	72°F.	66°F.	90	8:00 a.m.

single paper liner, the lettuce arrived at the retail store in excellent condition. This indicates that the use of ice and a paper liner to cut down air circulation is one of the best methods of assuring a good pack when the lettuce reaches the retail store.

Lettuce - Experiment XIII

On Table U, it will be noted that hydrocooling lettuce for five minutes in an overhead-type of hydrocooler (Figure 8) had no lasting effect as far as maintaining a low temperature during the marketing operation was concerned.

At only one point in this experiment was the temperature low enough to inhibit deterioration. That was immediately after hydrocooling. Deterioration is inhibited according to Platenius (34) when the temperature is 55°F. or lower.

When all four boxes arrived at the retail store, there were varying degrees of browning of the butts and lower outer leaves of all heads. The deterioration in the control box was more pronounced. The lettuce in the control box had also become wilted, and some of the heads in the top layer were slimy.

Lettuce - Experiment XIV

Hydrocooling lettuce for ten minutes in an overhead-type hydrocooler, the temperature of the water

TABLE U

Temperature

Experiment XIII — Lettuce - Hydrocooler for 5 Minutes — August 16,17, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	75°F.	75°F.	75°F.	75°F.	87°F.	78°F.	68	10:00 a.m.
In Packing Plant	1 hr.	76°F.	76°F.	76°F.	76°F.	76°F.	82°F.	62	11:00 a.m.
In Packing Plant	2 hrs.	78°F.	76°F.	77°F.	77°F.	82°F.	83°F.	59	12:00 a.m.
In Packing Plant	2 hrs. 30 min.	79°F.	79°F.	79°F.	79°F.	76°F.	83°F.	59	12:30 p.m.
After Hydrocooling	3 hrs.	53°F.	52°F.	49°F.	79°F.	77°F.	84°F.	58	1:00 p.m.
Warehouse	11 hrs.	57°F.	58°F.	54°F.	77°F.	66°F.	67°F.	89	9:00 p.m.
Retail Store	22 hrs.	61°F.	64°F.	62°F.	75°F.	71°F.	67°F.	92	8:00 a.m.

TABLE V

Temperature

Experiment XIV — Lettuce - Hydrocooler for 10 Minutes — August 16-17, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R. H.	Time of Exp.
Harvest Time	0 hrs.	75°F.	75°F.	75°F.	75°F.	87°F.	78°F.	68	10:00 a.m.
In Packing Plant	1 hr.	77°F.	77°F.	76°F.	77 F.	76°F.	82°F.	62	11:00 a.m.
In Packing Plant	2 hrs.	77°F.	77°F.	77°F.	77°F.	82°F.	83°F.	59	12:00 p.m.
In Packing Plant	2 hrs. 30 min.	80°F.	79°F.	78°F.	79°F.	76°F.	83°F.	59	12:30 p.m.
After Hydrocooling	3 hrs.	50°F.	49°F.	48°F.	80°F.	77°F.	84°F.	58	1:00 p.m.
Warehouse	11 hrs.	57°F.	55°F.	57°F.	74°F.	66°F.	67°F.	68	9:00 p.m.
Retail Store	22 hrs.	59°F.	59°F.	61°F.	75°F.	71°F.	67°F.	92	8:00 a.m.

in the hydrocooler being 40°F., gave slightly better results than in the preceding experiment when the lettuce was hydrocooled for only five minutes; however, there was only one point during the marketing operation at which the temperature of the experimental boxes were low enough to inhibit deterioration. This was immediately after hydrocooling. From this point on, there was a steady increase in the temperature (Table V).

By the time the lettuce had arrived at the retail store, the temperature in the three hydrocooled boxes had risen, and there was severe browning in the butts and lower outer leaves of all heads of lettuce. The lettuce in the control box by this time showed browning on the butts and lower outer leaves. A number of heads in the control box had also become wilted and slimy.

As in the preceding experiments, the results indicate that while hydrocooling is very efficient in removing field heat and lowering the temperature to some degree, ice or some other refrigerant is necessary to maintain a low temperature throughout the marketing operation.

Lettuce - Experiment XV

It will be noted on Table W that hydrocooling the lettuce for fifteen minutes in an overhead-type

TABLE V

Temperature

Experiment XV — Lettuce - Hydrocooler for 15 Minutes — August 18-19, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	74°F.	74°F.	74°F.	74°F.	85°F.	77°F.	82	10:00 a.m.
In Packing Plant	1 hr.	76°F.	75°F.	74°F.	76°F.	76°F.	80°F.	80	11:00 a.m.
In Packing Plant	2 hrs.	77°F.	76°F.	75°F.	77°F.	81°F.	81°F.	77	12:00 p.m.
In Packing Plant	2 hrs. 30 min.	77°F.	77°F.	76°F.	77°F.	77°F.	82°F.	77	12:30 p.m.
After Hydrocooling	3 hrs.	42°F.	40°F.	41°F.	77°F.	78°F.	83°F.	76	1:00 p.m.
Warehouse	11 hrs.	55°F.	52°F.	61°F.	80°F.	74°F.	75°F.	84	9:00 p.m.
Retail Store	22 hrs.	61°F.	56°F.	56°F.	79°F.	77°F.	74°F.	86	9:00 a.m.

hydrocooler (Fig. 6), the temperature of the water in the hydrocooler being 39°F., had approximately the same effect in lowering the temperature as did the two preceding experiments where hydrocooling was the only means of refrigeration used. The temperature drop caused by hydrocooling in this experiment was sufficient to bring the lettuce well within the protective temperature range of 55°F. as recommended by Platenius (34). But immediately after hydrocooling, the temperature began to increase steadily and by the time the lettuce arrived at the retail store, the temperature in the three experimental boxes averaged 58°F., just slightly above the minimum protective temperature.

All four boxes of lettuce showed varying degrees of browning. The three experimental boxes had browned on the butts and just the faintest bit of browning showed on the lower outer leaves. In the control box, there was pronounced browning of the butts and outer leaves, and the lettuce in the top layer had begun to wilt and get slimy.

Lettuce - Experiment XVI

Hydrocooling lettuce for as long as twenty minutes in an overhead-type hydrocooler (Fig. 6), the temperature of the water in the hydrocooler being 40°F., was not a great deal more effective than hydrocooling them for five minutes. This will be evident by comparing

TABLE X

Temperature

Experiment XVI — Lettuce - Hydrocooler for 20 Minutes — August 18-19, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	74°F.	74°F.	74°F.	74°F.	85°F.	77°F.	82	10:00 a.m.
In Packing Plant	1 hr.	75°F.	75°F.	73°F.	76°F.	77°F.	80°F.	80	11:00 a.m.
In Packing Plant	2 hrs.	77°F.	75°F.	74°F.	77°F.	81°F.	82°F.	77	12:00 p.m.
In Packing Plant	2 hrs. 30 min.	77°F.	76°F.	74°F.	77°F.	77°F.	82°F.	77	12:30 p.m.
After Hydrocooling	3 hrs.	40°F.	40°F.	39°F.	77°F.	79°F.	84°F.	76	1:00 p.m.
Warehouse	11 hrs.	54°F.	53°F.	53°F.	80°F.	74°F.	76°F.	84	9:00 p.m.
Retail Store	22 hrs.	58°F.	58°F.	58°F.	70°F.	77°F.	74°F.	86	8:00 a.m.

Tables U and X. The refrigerating effect of hydrocooling alone is a temporary one, and almost immediately after hydrocooling, the temperature began to rise.

By the time they had arrived at the retail store, all four boxes of lettuce showed deterioration in varying degrees. In the three boxes that had been hydrocooled, there was browning on the butts and lower outer leaves of the lettuce heads. On the other hand, the lettuce in the control box was severely browned on the butts and lower outer leaves. In the top layers of lettuce, the heads had become wilted and were beginning to become slimy.

In the preceding four experiments using only hydrocooling as a means of controlling the temperature of the produce as it moved through the marketing channels indicated very definitely that some other refrigerant should also have been used in conjunction with hydrocooling. The results of the preceding four experiments would also seem to indicate that hydrocooling is very efficient for the removal of field heat from produce but the effect of hydrocooling is only temporary, and some other refrigerant is needed to further lower the temperature and maintain it at a low level during the market operation.

Lettuce - Experiment XVII

It will be noted on Table Y that hydrocooling

TABLE X

Temperature

Experiment XVII Lettuce - Hydrocooler 5 Minutes - Top Iced with 10 lbs. of No. 1 Ice - Single Paper Liner — July 31, 1950 August 1, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Ext. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	78°F.	78°F.	78°F.	78°F.	88°F.	83°F.	72	10:00 a.m.
In Packing Plant	1 hr.	83°F.	83°F.	82°F.	83°F.	92°F.	86°F.	60	11:00 a.m.
In Packing Plant	2 hrs.	83°F.	83°F.	84°F.	83°F.	80°F.	90°F.	56	12:00 p.m.
In Packing Plant	3 hrs.	83°F.	84°F.	84°F.	83°F.	81°F.	91°F.	57	1:00 p.m.
In Packing Plant	5 hrs. 30 min.	84°F.	84°F.	85°F.	84°F.	80°F.	90°F.	51	3:30 p.m.
After Hydro-cooling Be-fore Icing	6 hrs. 15 min.	59°F.	55°F.	56°F.	84°F.	78°F.	89°F.	57	4:15 p.m.
Warehouse	13 hrs.	41°F.	49°F.	46°F.	86°F.	80°F.	70°F.	90	11:00 p.m.
Retail Store	22 hrs.	50°F.	51°F.	48°F.	89°F.	78°F.	72°F.	91	8:00 a.m.

the lettuce in an overhead-type hydrocooler (Fig. 6) for five minutes, the temperature of the water being 39°F., and then top icing with 20 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner gave satisfactory results in maintaining a low temperature and preventing deterioration.

Using this method of hydrocooling and icing, the temperature in the experimental boxes was held in the upper 40's and lower 50's during the remainder of the marketing operation. In all three of the experimental boxes, the ice had completely melted by the time it reached the retail store, but there was no evidence of any type of visible deterioration. The control box, on the other hand, showed very severe browning of the butts and lower outer leaves, and the lettuce in the entire box had become wilted, and some of the heads had even become slimy.

Lettuce - Experiment XVIII

Hydrocooling lettuce for ten minutes in an overhead-type hydrocooler (Fig. 6), the temperature of the water in the hydrocooler being 38°F., and then top icing the lettuce with 20 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner gave excellent results.

Using this combination of hydrocooling and icing, the temperature in the experimental boxes was

TABLE 2

Temperature

Experiment XVIII Lettuce - Hydrocooled for 10 Minutes--Top Iced with 20 lbs. of No. 1 Ice - Single Paper Liner August 9-10, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	75°F.	72°F.	87	10:00 a.m.
In Truck In Field	1 hr.	82°F.	82°F.	82°F.	82°F.	80°F.	76°F.	81	11:00 a.m.
Before Hydrocooling and Icing	2 hrs.	84°F.	84°F.	85°F.	85°F.	82°F.	80°F.	76	12:00 p.m.
After Hydrocooling and Icing	2 hrs. 30 min.	55°F.	55°F.	55°F.	85°F.	80°F.	81°F.	76	12:30 p.m.
After Hydrocooling and Icing	3 hrs.	49°F.	48°F.	48°F.	86°F.	80°F.	82°F.	76	1:00 p.m.
Warehouse	11 hrs.	45°F.	45°F.	46°F.	87°F.	82°F.	77°F.	86	9:00 p.m.
Retail Store	22 hrs.	47°F.	48°F.	47°F.	82°F.	79°F.	75°F.	88	8:00 a.m.

maintained in the lower and upper 40's (Table Z) during the remainder of the marketing operation, well below the critical temperature of 55°F. recommended by Platenius (34).

Ice in the three experimental boxes had completely melted by the time the lettuce had reached the retail store but there was no visible evidence of any type of deterioration in any of the three boxes. In the control box, however, there was very severe browning of the butts and lower outer leaves, and the heads in the entire box had become wilted and slimy.

Lettuce - Experiment XIX

It will be noted on Table AA that hydrocooling the lettuce for fifteen minutes in an overhead-type hydrocooler (Fig. 6), the temperature of the water in the hydrocooler being 39°F., and then top icing of the lettuce with 20 lbs. of No. 1 ice and enclosing the entire pack with a single paper liner gave excellent results.

The results were good both from a standpoint of maintaining a lower temperature and the preventing of deterioration. After hydrocooling and icing, the temperature in the experimental boxes were held in the lower and upper 40's during the remainder of the marketing operation.

By the time the lettuce had reached the retail store, the ice in the three experimental boxes had completely

TABLE AA

Temperature

Experiment XIX — Lettuce - Hydrocooler for 15 Minutes - Top Iced with 20 lbs. of No. 1 Ice — Single Paper Liner — August 9-10, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	75°F.	72°F.	87	10:00 a.m.
In Truck In Field	1 hr.	82°F.	82°F.	82°F.	82°F.	80°F.	76°F.	81	11:00 a.m.
Before Hydro-cooling and Icing	2 hrs.	85°F.	86°F.	85°F.	85°F.	82°F.	80°F.	76	12:00 p.m.
After Hydrocooling and Icing	2 hrs. 30 min.	51°F.	52°F.	51°F.	85°F.	80°F.	81°F.	76	12:30 p.m.
After Hydrocooling and Icing	3 hrs.	48°F.	48°F.	48°F.	86°F.	80°F.	82°F.	76	1:00 p.m.
Wholesale Warehouse	11 hrs.	43°F.	43°F.	43°F.	87°F.	82°F.	77°F.	86	9:00 p.m.
Retail Store	22 hrs.	45°F.	44°F.	43°F.	82°F.	79°F.	75°F.	88	8:00 a.m.

melted, but there was no visible evidence of any type of deterioration in any of the three boxes. In the control box, there was very severe browning of the butts and lower outer leaves. The heads in the entire box had become slimy and wilted.

Lettuce - Experiment XX

Hydrocooling the lettuce for twenty minutes in an overhead-type hydrocooler (Fig. 6), the temperature of the water in the hydrocooler being 40°F., top icing the lettuce with 20 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner gave excellent results. Using this method of hydrocooling and icing, the temperature in the experimental boxes was maintained in the lower 40's during the remainder of the marketing operation. These temperatures were well below the critical temperature of 55°F. as recommended by Platenius (34).

The ice in all three boxes had completely melted by the time the lettuce had arrived at the retail store, but there was no visible signs of deterioration present in the three experimental boxes. The control box, on the other hand, showed severe browning of the butts and lower outer leaves, and the entire box of lettuce had become wilted. Some of the heads had even become slimy.

In the four preceding experiments where hydrocooling, icing and paper liners were used, the lettuce

TABLE BB

Temperature

Experiment XX — Lettuce - Hydrocooled for 20 Minutes - Top Iced with 20 lbs. of No. 1 Ice — August 9-10, 1951

Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	75°F.	72°F.	87	10:00 a.m.
In Truck In Field	1 hr.	82°F.	82°F.	83°F.	82°F.	80°F.	76°F.	81	11:00 a.m.
Before Hydrocooling and Icing	2 hrs.	85°F.	86°F.	85°F.	85°F.	82°F.	80°F.	76	12:00 p.m.
After Hydrocooling and Icing	2 hrs. 30 min.	48°F.	48°F.	49°F.	85°F.	80°F.	81°F.	76	12:30 p.m.
After Hydrocooling and Icing	3 hrs.	45°F.	45°F.	45°F.	86°F.	80°F.	82°F.	76	1:00 p.m.
Warehouse	11 hrs.	42°F.	42°F.	42°F.	87°F.	82°F.	77°F.	86	9:00 p.m.
Retail Store	22 hrs.	43°F.	43°F.	43°F.	82°F.	79°F.	75°F.	88	8:00 a.m.

arrived at the retail store in excellent condition. These results would seem to indicate that hydrocooling to remove field heat, ice to control vital heat, and a paper liner to cut down air circulation is one of the best methods of assuring a good pack of lettuce upon reaching the retail store.

Lettuce - Experiment XXI

In this experiment, the lettuce was cold-air precooled in a cold storage room for forty-six hours or until the lettuce had reached an average temperature of 35°F. (Table CC). Upon removal, the three experimental boxes were topiced with 10 lbs. of No. 1 ice and shipped through the normal marketing channels.

This method of precooling and icing proved satisfactory both from a standpoint of maintaining a low temperature and preventing deterioration. The only disadvantage of the above method was the length of time it took by this means of precooling to lower the temperature well within the protective range.

When the lettuce arrived at the retail store, the ice in all three experimental boxes had melted by this time, and the heads in the top layers of each box showed slight signs of browning on the butts. In comparison, the lettuce in the control box had become brown on the butts and lower outer leaves, and all heads were

TABLE CC

Temperature

Experiment XXI — Lettuce - Cold Air Precooled - Removed and Top Iced with 10 lbs. of No. 1 Ice — July 31, 1951 August 1-2, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	76°F.	76°F.	76°F.	76°F.	74°F.	72°F.	88	9:00 a.m.
In Truck In Field	1 hr.	82°F.	81°F.	83°F.	82°F.	79°F.	77°F.	85	9:00 a.m.
In Truck In Field	2 hrs.	86°F.	88°F.	87°F.	87°F.	84°F.	80°F.	76	10:00 a.m.
In Packing Plant	3 hrs.	88°F.	88°F.	89°F.	88°F.	85°F.	84°F.	72	11:00 a.m.
Before Being Placed in Cooler	4 hrs.	90°F.	90°F.	91°F.	90°F.	79°F.	87°F.	66	12:00 p.m.
In Cooler	5 hrs.	90°F.	89°F.	89°F.	86°F.	34°F.			1:00 p.m.
In Cooler	6 hrs.	87°F.	88°F.	87°F.	86°F.	33°F.			2:00 p.m.
In Cooler	7 hrs.	85°F.	86°F.	86°F.	85°F.	33°F.			3:00 p.m.
In Cooler	8 hrs.	85°F.	84°F.	83°F.	83°F.	34°F.			4:00 p.m.

Temperature

TABLE CC

Experiment XXI — Lettuce - Cold Air Precooled - Removed and Top Iced with 10 lbs. of No. 1 Ice — July 20-21, 1951 August 1, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
									July 31
In Cooler	26 hrs.	59°F.	60°F.	59°F.	57°F.	33°F.			10:00 a.m.
In Cooler	27 hrs.	57°F.	58°F.	57°F.	57°F.	33°F.			11:00 a.m.
In Cooler	28 hrs.	56°F.	57°F.	56°F.	57°F.	33°F.			12:00 p.m.
In Cooler	29 hrs.	55°F.	56°F.	55°F.	56°F.	32°F.			1:00 p.m.
In Cooler	30 hrs.	55°F.	55°F.	53°F.	55°F.	33°F.			2:00 p.m.
In Cooler	31 hrs.	54°F.	54°F.	53°F.	55°F.	34°F.			3:00 p.m.
									August 1
In Cooler	50 hrs.	37°F.	35°F.	35°F.	36°F.	33°F.	77°F.	88	10:00 a.m.
Removed from cooler & Iced	51 hrs.	36°F.	35°F.	35°F.	35°F.	79°F.	77°F.	88	12:00 p.m.
After Icing	52 hrs.	38°F.	38°F.	39°F.	38°F.	78°F.	80°F.	84	1:00 p.m.
Warehouse	60 hrs.	41°F.	42°F.	42°F.	69°F.	74°F.	68°F.	67	9:00 p.m.
									August 2
Retail Store	71 hrs.	45°F.	44°F.	45°F.	79°F.	75°F.	68°F.	72	8:00 a.m.

wilted and slimy.

The results of the experiment are substantiated by the observations of Platenius (35) who noted that holding lettuce at a temperature of 35°F. from a few days to several weeks had no noticeable effect on the subsequent rate of breakdown when these vegetables were later transferred to higher temperatures.

Lettuce - Experiment XXII

Here again as in the preceding experiment, the lettuce was precooled by means of a cold storage room for forty-six hours or until the temperature in all three of the experimental boxes had been lowered to 35°F. Upon the removal of the lettuce from the cold storage room, they were top iced with 10 lbs. of No. 1 ice, and the entire pack was enclosed in a single paper liner then shipped through the normal marketing channels.

This method of precooling and icing also proved to be an excellent method to maintain a low temperature and to prevent deterioration. By the time the lettuce had reached the retail store, there were only a few scattered pieces of ice left in the three experimental boxes but the lettuce was in excellent condition showing no visible deterioration. In the control box, it was a completely different story. The butts and lower outer leaves of all heads were severely browned, and the heads

Temperature

TABLE DD

Experiment XXII Lettuce - Cold Air Precooled - Removed Top Iced with 10 lbs. of No. 1 Ice - Single Paper Liner August 6-7-8-9, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	66°F.	66°F.	66°F.	66°F.	64°F.	69°F.	80	8:00 a.m.
In Truck In Field	1 hr.	72°F.	72°F.	73°F.	72°F.	69°F.	66°F.	65	9:00 a.m.
In Truck In Field	2 hrs.	76°F.	78°F.	75°F.	76°F.	75°F.	69°F.	65	10:00 a.m.
In Packing Plant	3 hrs.	79°F.	79°F.	79°F.	79°F.	77°F.	72°F.	52	11:00 a.m.
Before Being Placed in Cooler	4 hrs.	80°F.	80°F.	80°F.	80°F.	75°F.	73°F.	49	12:00 p.m.
In Cooler	5 hrs.	80°F.	80°F.	80°F.	80°F.	34°F.			1:00 p.m.
In Cooler	6 hrs.	79°F.	79°F.	78°F.	79°F.	34°F.			2:00 p.m.
In Cooler	7 hrs.	78°F.	79°F.	78°F.	78°F.	34°F.			3:00 p.m.
In Cooler	8 hrs.	78°F.	78°F.	77°F.	78°F.	34°F.			4:00 p.m.

Temperature

TABLE DD

Experiment XXII — Lettuce - Cold Air Precooled - Removed Top Iced with 10 lbs. of No. 1 Ice — August 6-7-8-9 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
									August 7
In Cooler	26 hrs.	57°F.	56°F.	58°F.	58°F.	33°F.			10:00 a.m.
In Cooler	27 hrs.	57°F.	56°F.	58°F.	57°F.	33°F.			11:00 a.m.
In Cooler	28 hrs.	57°F.	56°F.	57°F.	57°F.	33°F.			12:00 p.m.
In Cooler	29 hrs.	56°F.	56°F.	56°F.	57°F.	34°F.			1:00 p.m.
In Cooler	30 hrs.	56°F.	55°F.	55°F.	56°F.	34°F.			2:00 p.m.
In Cooler	31 hrs.	55°F.	55°F.	55°F.	56°F.	34°F.			3:00 p.m.
In Cooler	32 hrs.	55°F.	55°F.	54°F.	55°F.	34°F.			4:00 p.m.
									August 8
In Cooler	50 hrs.	35°F.	35°F.	36°F.	36°F.	33°F.			10:00 a.m.
In Cooler	51 hrs.	35°F.	35°F.	35°F.	35°F.	69°F.	64°F.	88	12:00 p.m.
Warehouse	59 hrs.	40°F.	40°F.	41°F.	73°F.	71°F.	63°F.	88	9:00 p.m.
									August 9
Retail Store	70 hrs.	42°F.	42°F.	42°F.	78°F.	72°F.	66°F.	81	8:00 a.m.

had become wilted and slimy.

Using a cold room as a means of precooling, the preceding two experiments have given very satisfactory results from the standpoint of insuring an excellent pack of lettuce upon arrival at the retail store. But, it should be pointed out that the big disadvantage in this method of precooling is the length of time it took to lower the temperature of the lettuce to a protective temperature. By consulting Tables CC and DD, this time element will be very evident.

Celery

Celery was iced and/or hydrocooled during the seasons of 1950 and 1951 in the packing shed at the De Vincent Brothers' farm in Waltham, Massachusetts. The same evening of icing and/or hydrocooling, the lettuce was transported by truck to the First National Warehouse in Somerville, Massachusetts. These experiments were conducted over a period of from eleven to twelve hours.

Methods of Packing, Icing and Hydrocooling

Celery was harvested between 8:00 a.m. and 9:00 a.m. Upon reaching the packing shed, it was sorted, trimmed, washed, bunched and packed into half-bushel boxes with twelve bunches to each box arranged in three layers with four bunches in each layer (Figs. 7, 8, 9, 10, 11, and 12).

Figure 7
Celery In
Field Boxes
Immediately
After Harvest

Figure 8
Celery In
Field Boxes
Before
Trimming And
Grading

Figure 9
Field Boxes of Celery
Being Loaded Onto Truck

Figure 10
Celery in Packing Shed
Being Sorted and Washed

Four boxes of celery were used in each experiment--three for experimental purposes and one as a control.

History of Produce

Celery was iced and/or hydrocooled between 12:00 p.m. and 1:00 p.m. At approximately 7:00 p.m. the same evening, the lettuce was transported by truck to the warehouse arriving in Somerville at approximately 8:00 p.m.

Celery - Experiment I

Top icing celery with 10 lbs. of No. 3 ice gave fairly satisfactory results. By the time the celery had reached the warehouse in Somerville, Massachusetts, the temperature in all three experimental boxes had dropped below the critical temperature of 55°F. as recommended by Platenius (34).

At the warehouse, the ice in the three experimental boxes had completely melted, and the leaves on the bunches of celery were just starting to wilt. In comparison, the celery leaves in the control box were completely wilted, and the stalks themselves had lost their fresh crispness and were limp and stringy.

Celery - Experiment II

It will be noted on Table FF that center icing the celery boxes with 10 lbs. of No. 3 ice proved very satisfactory from a standpoint of maintaining a low temperature and preventing deterioration.

When the celery arrived at the warehouse at 8:00 p.m., eleven hours from the time of harvest and eight hours from the time of icing, the temperature in the three experimental boxes averaged 46°F. The temperature in the control box was 84°F., and the atmospheric temperature had dropped to 74°F. (Table FF). By this time, approximately two-thirds of the ice in the three experimental boxes had melted, but the celery in these boxes was in excellent condition with no visible deterioration present. In the control box, on the other hand, all the celery leaves had become wilted, and the celery stalks had lost their fresh crispness and were becoming limp.

It is noteworthy that the temperature in the control box remained remarkably uniform, and for the most part below the atmospheric temperature. This indicates that celery does not evolve as an appreciable quantity of heat as does the two preceding crops of asparagus and lettuce. This observation is substantiated by the findings of Rose, et. al (38). These workers noted that celery evolved only 13,520 B. t. u. per ton in twenty-four hours when stored at a temperature of 60°F. as compared with asparagus and lettuce which evolve 78,460 and 45,980 B. t. u.'s when stored under the same conditions.

Temperature

TABLE IX

Experiment I — Celery - Top Iced with 10 lbs. of No. 5 Ice — August 9-10, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	73°F.	73°F.	73°F.	73°F.	75°F.	71°F.	74	9:00 a.m.
Bunches in Field	1 hr.	77°F.	77°F.	77°F.	77°F.	81°F.	75°F.	66	10:00 a.m.
Bunches in Field Boxes	2 hrs.	81°F.	82°F.	81°F.	80°F.	84°F.	80°F.	60	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	82°F.	82°F.	81°F.	81°F.	88°F.	72°F.	56	11:30 a.m.
After Washing and Icing	3 hrs.	79°F.	80°F.	80°F.	81°F.	86°F.	84°F.	55	12:00 p.m.
In Packing Plant	5 hrs.	66°F.	66°F.	66°F.	84°F.	87°F.	88°F.	45	2:00 p.m.
In Packing Plant	6 hrs.	56°F.	57°F.	57°F.	86°F.	88°F.	89°F.	45	3:00 p.m.
Wholesale Market	11 hrs.	51°F.	52°F.	53°F.	87°F.	84°F.	79°F.	58	8:00 p.m.

Temperature

TABLE FF

Experiment II — Celery - Center Iced with 10 lbs. of No. 5 Ice — September 1-2, 19[illegible]

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	73°F.	73°F.	73°F.	73°F.	75°F.	73°F.	95	9:00 a.m.
Bunches in Field	1 hr.	76°F.	75°F.	76°F.	76°F.	80°F.	76°F.	96	10:00 a.m.
Bunches in Field Boxes	2 hrs.	80°F.	81°F.	81°F.	80°F.	83°F.	80°F.	96	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	80°F.	81°F.	82°F.	81°F.	85°F.	82°F.	90	11:30 a.m.
After Washing and Icing	3 hrs.	80°F.	80°F.	80°F.	81°F.	87°F.	84°F.	80	12:00 p.m.
In Packing Plant	5 hrs.	67°F.	67°F.	67°F.	83°F.	85°F.	76°F.	91	2:00 p.m.
In Packing Plant	6 hrs.	54°F.	52°F.	54°F.	84°F.	85°F.	77°F.	88	3:00 p.m.
Wholesale Market	11 hrs.	46°F.	48°F.	46°F.	84°F.	73°F.	74°F.	94	8:00 p.m.

Celery - Experiment III

Bottom icing the three experimental boxes of celery with 10 lbs. of No. 5 ice in this experiment proved unsatisfactory from the standpoint of maintaining a low temperature and preventing deterioration (Table GG). It was found to be impossible to maintain a low temperature using this method of icing. The lowest temperature obtainable during the entire experiment was 57°F., two degrees above the critical temperature of 55°F. as recommended by Platenius (34). The celery in the three iced boxes upon arrival at the warehouse showed wilting of the leaves in the upper layers of all three boxes. There was also pitting of the celery stalks in all three boxes in the bottom layer. This pitting was caused by the sharp pieces of ice in the bottom of the box with the pressure of the upper layers of celery forcing the bottom layers against the ice.

In the control box, the celery leaves had all become wilted, and the stalks themselves had begun to lose their fresh crispness and were becoming limp and stringy.

Celery - Experiment IV

Top and center icing the celery boxes with 5 lbs. of No. 5 ice produced excellent results both from a standpoint of maintaining a low temperature and the prevention of deterioration. Immediately after icing, the temperature in the three experimental boxes began to drop

Temperature

TABLE GG

Experiment III — Celery - Bottom Iced with 10 lbs. of No. 5 Ice — September 5-6, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	73°F.	69°F.	90	8:00 a.m.
Bunches in Field	2 hrs.	75°F.	75°F.	75°F.	75°F.	79°F.	74°F.	85	10:00 a.m.
Bunches in Field Boxes	3 hrs.	77°F.	77°F.	77°F.	77°F.	80°F.	78°F.	80	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	78°F.	78°F.	78°F.	78°F.	83°F.	79°F.	80	11:30 a.m.
After Washing and Icing	4 hrs.	77°F.	77°F.	76°F.	78°F.	81°F.	80°F.	76	12:00 p.m.
In Packing Plant	6 hrs.	68°F.	68°F.	67°F.	79°F.	88°F.	83°F.	74	2:00 p.m.
In Packing Plant	7 hrs.	62°F.	62°F.	62°F.	81°F.	86°F.	83°F.	74	3:00 p.m.
Wholesale Market	12 hrs.	58°F.	57°F.	58°F.	79°F.	73°F.	70°F.	78	8:00 p.m.

Temperature

TABLE HH

Experiment IV — Celery - Top and Center Each Iced with 10 lbs. of No. 10 Ice — August 7-8, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	67°F.	61°F.	85	8:00 a.m.
Bunches in Field	2 hrs.	68°F.	68°F.	68°F.	68°F.	71°F.	68°F.	65	10:00 a.m.
Bunches in Field Boxes	3 hrs.	72°F.	71°F.	71°F.	71°F.	75°F.	70°F.	63	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	73°F.	73°F.	72°F.	72°F.	78°F.	72°F.	58	11:30 a.m.
After Washing and Icing	4 hrs.	70°F.	72°F.	67°F.	74°F.	75°F.	73°F.	52	12:00 p.m.
In Packing Plant	6 hrs.	61°F.	62°F.	61°F.	75°F.	79°F.	74°F.	48	2:00 p.m.
In Packing Plant	7 hrs.	52°F.	52°F.	53°F.	77°F.	79°F.	75°F.	49	3:00 p.m.
Wholesale Market	12 hrs.	47°F.	47°F.	46°F.	77°F.	66°F.	60°F.	60	8:00 p.m.

and by the time the celery reached the warehouse, the temperature in the three experimental boxes averaged 47°F. (Table HH).

Upon the arrival of the celery at the warehouse, the ice was approximately half melted, but there was no evidence of any deterioration in the three iced boxes. In the control box, however, the celery leaves had become severely wilted in all three of the layers.

Celery - Experiment V

The application of 5 lbs. of No. 5 ice to the top, center and bottom gave excellent results both from a standpoint of maintaining a low temperature and preventing deterioration.

The temperature dropped rapidly after icing, and by the time the celery had reached the warehouse, the temperature in the three experimental boxes averaged 47°F. (Table II).

At the warehouse, the ice in the three experimental boxes had completely melted, but there was no evidence of any deterioration in the iced boxes. In the control box, on the other hand, the celery leaves were wilted, and the stalks had lost their fresh crispness and were becoming limp and stringy.

Celery - Experiment VI

In this experiment, the celery was iced with

Temperature

TABLE II

Experiment V — Celery - Top, Center and Bottom Iced Each with 5 lbs. of No. 5 Ice — August 30-31, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	69°F.	69°F.	69°F.	69°F.	73°F.	69°F.	84	8:00 a.m.
Bunches in Field	2 hrs.	74°F.	74°F.	74°F.	74°F.	76°F.	72°F.	77	10:00 a.m.
Bunches in Field Boxes	3 hrs.	77°F.	77°F.	77°F.	77°F.	79°F.	75°F.	70	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	77°F.	78°F.	78°F.	78°F.	78°F.	76°F.	70	11:30 a.m.
After Washing and Icing	4 hrs.	77°F.	78°F.	76°F.	78°F.	81°F.	76°F.	70	12:00 p.m.
In Packing Plant	5 hrs.	64°F.	63°F.	63°F.	80°F.	82°F.	77°F.	69	2:00 p.m.
In Packing Plant	7 hrs.	53°F.	52°F.	52°F.	81°F.	81°F.	79°F.	69	3:00 p.m.
Wholesale Market	12 hrs.	46°F.	47°F.	47°F.	80°F.	72°F.	68°F.	77	8:00 p.m.

Temperature

TABLE JJ

Experiment VI — Celery - Top Iced with 10 lbs. of No. 5 Ice — July 24-25, 1950
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	61°F.	61°F.	61°F.	61°F.	67°F.	63°F.	80	8:00 a.m.
Bunches in Field	2 hrs.	68°F.	68°F.	68°F.	68°F.	75°F.	72°F.	66	10:00 a.m.
Bunches in Field Boxes	3 hrs.	72°F.	72°F.	72°F.	72°F.	80°F.	76°F.	50	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	72°F.	73°F.	73°F.	72°F.	81°F.	77°F.	50	11:30 a.m.
After Washing and Icing	3 hrs. 40 min.	71°F.	70°F.	72°F.	71°F.	82°F.	77°F.	50	11:40 a.m.
In Packing Plant	5 hrs.	57°F.	58°F.	59°F.	74°F.	84°F.	78°F.	46	1:00 p.m.
In Packing Plant	6 hrs.	41°F.	43°F.	44°F.	75°F.	73°F.	80°F.	46	2:00 p.m.
Wholesale Market	12 hrs.	37°F.	39°F.	38°F.	75°F.	74°F.	68°F.	83	8:00 p.m.

10 lbs. of No. 5 ice, and the entire pack was enclosed in a single paper liner. The results of this method of icing were satisfactory with the temperature being maintained well below the critical temperature of 55°F. and, for the most part in the upper 30's and lower 40's (Table JJ), as recommended by Platenius (34).

By the time the celery reached the warehouse, approximately half of the ice in the three experimental boxes had melted, but there was no evidence of any type of deterioration in the iced boxes; however, the control box showed wilting of the celery leaves, and the stalks had become limp and stringy.

In comparing Experiment V with Experiment VI, it will be noted that the amount and placement of ice was the same. The only difference in the two experiments was the use of a single paper liner in Experiment VI. The effect of the paper liner was a much lower temperature during the marketing operation and a far superior pack when the celery arrived at the warehouse. The temperature difference in the two methods will be evident by consulting Tables II and JJ.

Celery - Experiment VII

Using a single paper liner and center icing the celery boxes proved to be an excellent method both from a standpoint of maintaining a low temperature and

Temperature

TABLE KK

Experiment VII Celery - Center Iced with 10 lbs. of No. 5 Ice August 2-3, 1950
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	67°F.	64°F.	88	8:00 a.m.
Bunches in Field	2 hrs.	68°F.	68°F.	68°F.	68°F.	71°F.	67°F.	70	10:00 a.m.
Bunches in Field Boxes	3 hrs.	70°F.	71°F.	70°F.	71°F.	76°F.	69°F.	65	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	71°F.	72°F.	72°F.	71°F.	76°F.	69°F.	66	11:30 a.m.
After Washing and Icing	4 hrs.	70°F.	71°F.	70°F.	72°F.	74°F.	69°F.	72	12:00 p.m.
In Packing Plant	6 hrs.	52°F.	53°F.	53°F.	74°F.	75°F.	70°F.	70	2:00 p.m.
In Packing Plant	7 hrs.	42°F.	43°F.	42°F.	73°F.	73°F.	70°F.	72	3:00 p.m.
Wholesale Market	12 hrs.	39°F.	38°F.	38°F.	72°F.	72°F.	67°F.	67	8:00 p.m.

preventing deterioration.

Immediately after icing, the temperature in all three boxes began to drop (Table KK), and by the time the celery reached the warehouse, the temperature in the three iced boxes averaged 38°F., a temperature which is well within the protective temperature range.

At the warehouse, approximately half of the ice in the three experimental boxes had melted by this time, but there was no evidence of any type of deterioration in any of the iced boxes. In the control box, the celery leaves had just begun to wilt. Here again, by comparing Experiment II with Experiment VII, the only difference in the two experiments being the use of a paper liner, it will be noted that the temperatures in Experiment VII were lower during the marketing operation and a more superior pack arrived at the warehouse.

Celery - Experiment VIII

It will be noted on Table LL that bottom icing the celery boxes with 10 lbs. of No. 5 ice and enclosing the entire pack in a single paper liner gave fairly satisfactory results.

After icing, there was a slow drop in temperature until the celery reached the warehouse at which time the temperature in the three experimental boxes averaged 50°F. At this point, the ice in the three experimental

Temperature

TABLE LL

Experiment VIII Celery - Bottom Iced with 10 lbs. of No. 5 Ice August 4-5, 1950
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	76°F.	72°F.	70	9:00 a.m.
Bunches in Field	1 hr.	74°F.	74°F.	74°F.	74°F.	77°F.	74°F.	63	10:00 a.m.
Bunches in Field Boxes	2 hrs.	75°F.	75°F.	77°F.	76°F.	79°F.	77°F.	60	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	76°F.	76°F.	77°F.	77°F.	81°F.	77°F.	56	11:30 a.m.
After Washing and Icing	3 hrs.	76°F.	76°F.	76°F.	76°F.	80°F.	78°F.	56	12:00 p.m.
In Packing Plant	5 hrs.	64°F.	63°F.	64°F.	80°F.	85°F.	80°F.	54	2:00 p.m.
In Packing Plant	6 hrs.	56°F.	56°F.	56°F.	81°F.	84°F.	79°F.	54	3:00 p.m.
Wholesale Market	11 hrs.	50°F.	50°F.	50°F.	79°F.	74°F.	70°F.	62	8:00 p.m.

boxes had completely melted, but there was no evidence of any type of deterioration in any of the three boxes with the exception of a small amount of pitting of the stalks in the lower layers. This pitting was presumably caused by the shave ice in the bottom of the boxes, and the pressure of the upper layers of celery forcing the bottom layers down against the ice. In the control box, the celery leaves were very severely wilted, and the stalks had become limp and stringy.

Celery - Experiment IX

Top and center icing the celery boxes with 5 lbs. of No. 5 ice and enclosing the entire pack in a single paper liner proved to be the best method of celery preparation for market in the two seasons of work.

Immediately after icing, the temperature in the three experimental boxes began to drop, and by the time the celery arrived at the warehouse, the temperature in the three iced boxes averaged 37°F. (Table MM).

At the warehouse, the ice in the three experimental boxes had completely melted by this time, but there was no evidence of any type of deterioration in any of the three experimental boxes; however, in the control box, the celery leaves had become wilted in the upper layer.

Celery - Experiment X

It will be noted on Table NN that the application of 5 lbs. of No. 5 ice to the top, center and bottom

Temperature

TABLE XXX

Experiment IX Celery - Top and Center Each Iced with 5 lbs. of No. 5 Ice - Single Paper Liner July 26-27, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	70°F.	70°F.	70°F.	70°F.	77°F.	68°F.	67	8:00 a.m.
Bunches in Field	2 hrs.	70°F.	70°F.	70°F.	70°F.	78°F.	74°F.	57	10:00 a.m.
Bunches in Field Boxes	3 hrs.	74°F.	76°F.	75°F.	75°F.	82°F.	76°F.	52	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	75°F.	75°F.	76°F.	76°F.	80°F.	76°F.	52	11:30 a.m.
After Washing and Icing	3 hrs. 40 min.	75°F.	77°F.	75°F.	75°F.	82°F.	77°F.	52	11:40 a.m.
In Packing Plant	5 hrs.	62°F.	64°F.	63°F.	78°F.	83°F.	78°F.	52	1:00 p.m.
In Packing Plant	7 hrs.	45°F.	45°F.	46°F.	78°F.	82°F.	79°F.	50	3:00 p.m.
Wholesale Market	12 hrs.	38°F.	37°F.	37°F	77°F.	75°F.	70°F.	70	8:00 p.m.

Temperature

TABLE NN

Experiment X — Celery - Top, Center and Bottom Each Iced with 5 lbs. of Ice — July 28-29, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	73°F.	73°F.	73°F.	73°F.	80°F.	76°F.	60	9:00 a.m.
Bunches in Field	1 hr.	76°F.	76°F.	76°F.	76°F.	84°F.	79°F.	58	10:00 a.m.
Bunches in Field Boxes	2 hrs.	81°F.	80°F.	81°F.	81°F.	85°F.	83°F.	55	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	81°F.	83°F.	82°F.	81°F.	89°F.	84°F.	51	11:30 a.m.
After Washing and Icing	3 hrs.	80°F.	80°F.	81°F.	82°F.	88°F.	85°F.	48	12:00 p.m.
In Packing Plant	5 hrs.	65°F.	64°F.	64°F.	84°F.	87°F.	87°F.	45	2:00 p.m.
In Packing Plant	6 hrs.	47°F.	47°F.	46°F.	85°F.	85°F.	86°F.	43	3:00 p.m.
Wholesale Market	11 hrs.	36°F.	36°F.	37°F.	82°F.	76°F.	70°F.	75	8:00 p.m.

of the celery boxes and their enclosure in a single paper liner produced excellent results. As a matter of fact, this method produced the lowest temperature of any method used with celery in two seasons of experimentations.

After icing, the temperature in the three experimental boxes dropped rapidly, and by the time the celery had reached the warehouse, the temperature in the three experimental boxes had dropped to 36°F.

At the warehouse in the three experimental boxes, the ice was approximately half melted, and there was no evidence of any type of deterioration with the exception of pitting of the celery stalks in the bottom of the boxes where the celery was in contact with the sharp ice and wooded bottom of the boxes. This pitting was presumably caused by the pressure of the upper layers of celery forcing the bottom layers down against the ice in the bottom of the boxes. In the control box, the celery leaves were badly wilted and had begun to get slimy. Also, the celery stalks were limp and stringy.

Celery - Experiment XI

Hydrocooling the celery for ten minutes in an immersion-type hydrocooler (Fig. 13) and then top icing the boxes with 10 lbs. of No. 5 ice and enclosing the entire pack in a single paper liner produced satisfactory results from both a standpoint of maintaining low temper-

Temperature

TABLE OO

Experiment XI — Celery - Hydrocooler for 10 Minutes - Top Iced with 10 lbs. of No. 5 Ice - Single Paper Liner — August 20-21, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	55°F.	53°F.	65	8:00 a.m.
Bunches in Field	1 hr.	72°F.	72°F.	71°F.	71°F.	59°F.	63°F.	83	9:00 a.m.
In Packing Plant	2 hrs.	72°F.	72°F.	73°F.	73°F.	69°F.	63°F.	89	10:00 a.m.
In Packing Plant	3 hrs.	75°F.	74°F.	74°F.	74°F.	71°F.	63°F.	88	11:00 a.m.
In Packing Plant	4 hrs.	63°F.	62°F.	61°F.	75°F.	70°F.	68°F.	86	12:00 p.m.
After Hydro-cooling and Icing	4 hrs. 30 min.	56°F.	57°F.	56°F.	76°F.	70°F.	68°F.	86	12:30 p.m.
After Hydro-cooling and Icing	5 hrs.	54°F.	54°F.	54°F.	76°F.	76°F.	72°F.	90	1:00 p.m.
Wholesale Market	9 hrs.	47°F.	47°F.	46°F.	79°F.	74°F.	67°F.	90	5:00 p.m.

Figure 11
Celery Packed and Ready for Market

Figure 12
Immersion-type hydrocooler Used in
Experimental Work with Celery and Radishes

atures and preventing deterioration.

When the celery reached the warehouse, the temperature in the three experimental boxes averaged 47°F. (Table 00)--well within the protective temperature range of 55°F. as recommended by Platenius (34).

At the warehouse, one-third of the ice in the three experimental boxes had melted, but the celery was in excellent condition showing no deterioration in any of the experimental boxes. In the control box, however, the celery leaves had just begun to wilt.

Hydrocooling of celery is recommended by Zink (50). This worker reports that using an overhead-type precooling machine, the water of the precooler being at approximately 35°F., celery was precooled quickly and thoroughly.

Celery - Experiment XII

Hydrocooling the celery for fifteen minutes and then top icing the three experimental boxes with 10 lbs. of No. 5 ice produced very satisfactory results from a standpoint of both maintaining a low temperature and preventing deterioration.

Using a combination of hydrocooling and icing caused an immediate lowering of the temperature which continued to drop until at the warehouse the average temperature in the three experimental boxes was 44°F.

Temperature

TABLE QQ

Experiment XII — Celery - Hydrocooler for 15 Minutes - Top Iced with 10 lbs. of No. 5 Ice - Single Paper Liner — August 27-28, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	74°F.	74°F.	74°F.	74°F.	74°F.	73°F.	77	10:00 a.m.
Bunches in Field	1 hr.	79°F.	78°F.	79°F.	79°F.	79°F.	75°F.	75	11:00 a.m.
In Packing Plant	2 hrs.	62°F.	62°F.	63°F.	83°F.	79°F.	73°F.	76	12:00 p.m.
After Hydro-cooling and Icing	2 hrs. 30 min.	59°F.	58°F.	58°F.	83°F.	79°F.	73°F.	76	12:30 p.m.
After Hydro-cooling and Icing	3 hrs.	53°F.	52°F.	52°F.	83°F.	79°F.	74°F.	76	1:00 p.m.
Wholesale Warehouse	6 hrs.	44°F.	44°F.	44°F.	84°F.	78°F.	75°F.	69	5:00 p.m.

Upon the arrival of the celery at the warehouse, approximately half of the ice in the three experimental boxes had melted, but the celery was in excellent condition showing no evidence of deterioration at all. In the control box, however, the celery leaves were severely wilted, and the stalks had become limp and stringy.

In the preceding three experiments using hydrocooling to remove field heat quickly and thoroughly, package icing to maintain a low temperature during the marketing operation, and a paper liner to cut down air circulation proved to be one of the most effective methods for insuring a superior pack upon arrival at the warehouse.

Radishes

Radishes were iced and/or hydrocooled during the seasons of 1950 and 1951 in the packing shed at the DeVincent Brothers' farm in Waltham, Massachusetts. The same evening of icing and/or hydrocooling, the produce was transported by truck to the First National Warehouse in Somerville, Massachusetts. These experiments were conducted over a period of from twenty-two to twenty-four hours.

Methods of Packing, Icing and Hydrocooling

Radishes were harvested between 8:00 a.m. and 10:00 a.m. They were graded, bunched and packed into

bushel boxes right in the field with forty-eight bunches of radishes in each box (Figs. 13, 14 and 15). Upon reaching the packing shed, the boxes of radishes were further graded and washed to remove any loose soil adhering to the surface of the radish. Four boxes of radishes were used in each experiment--three for experimental purposes and one as a control.

History of Produce

Radishes were iced and/or hydrocooled between 11:00 a.m. and 12:00 p.m. At approximately 7:00 p.m. that evening, the radishes were trucked to the warehouse arriving in Somerville at approximately 8:00 p.m. The following morning, they were distributed to the retail stores.

Radishes - Experiment I

It will be noted on Table RR that packing 20 lbs. of block ice between the two rows of radishes, the radishes being arranged so that leaves faced toward the ice in the center of the box, produced unsatisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration.

At no time in the marketing operation did the temperature of the radishes drop to or below the minimum protective temperature of 55°F. as recommended by Platenius (34). This fact explains the poor condition of the radish leaves upon their arrival at the retail store.

Temperature

TABLE RR

Experiment I — Radishes - 20 lbs. of Block Ice Packed Between Two Rows of Radishes with Stems Facing Towards the Ice — August 7-8, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	70°F.	70°F.	70°F.	70°F.	67°F.	61°F.	85	8:00 a.m.
Bunches in Field	2 hrs.	74°F.	74°F.	74°F.	74°F.	71°F.	63°F.	65	10:00 a.m.
Bunches in Field	3 hrs.	78°F.	78°F.	78°F.	78°F.	75°F.	70°F.	63	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	78°F.	79°F.	79°F.	78°F.	78°F.	72°F.	58	11:30 a.m.
After Icing	4 hrs.	78°F.	79°F.	79°F.	78°F.	75°F.	73°F.	52	12:00 p.m.
In Packing Plant	6 hrs.	63°F.	65°F.	65°F.	79°F.	78°F.	74°F.	48	2:00 p.m.
Warehouse	12 hrs.	63°F.	64°F.	64°F.	77°F.	66°F.	60°F.	60	8:00 p.m.
Retail Store	24 hrs.	63°F.	65°F.	64°F.	75°F.	57°F.	49°F.	89	8:00 a.m.

Figure 13
Radishes Punched in Field

Figure 14
Radishes Punched in Field Box

Figure 15
Sadiches in Field Boxes

Figure 16
Ice Retail Display Case
Used in Controlled Experiments

One-fourth of the original 20 lbs. of block ice was still left in the three experimental boxes when they reached the retail store; however, the radish leaves had wilted completely in the three iced boxes, and in the control box, the leaves were completely wilted and some of them were beginning to become slimy.

Radishes - Experiment II

In this experiment, the placement of ice was 20 lbs. of block ice between the two rows of radishes. The stems of the radishes were arranged so that they faced away from the ice, and the entire pack was enclosed in a single paper liner. This method of icing proved fairly satisfactory from a standpoint of maintaining a low temperature, and preventing deterioration (Table SS). While the temperature in the three experimental boxes never dropped below the critical temperature of 55°F. as recommended by Platenius (34), the results of the experiment do indicate that the temperature was low enough to prevent any serious deterioration.

At the retail store, approximately one-fourth of the ice was left in the three experimental boxes, and the radish leaves were all in a good, fresh, green, non-wilted condition. In the control box, on the contrary, the leaves were entirely wilted and just beginning to become slimy.

Temperature

TABLE 33

Experiment II — Radishes - 20 lbs. of Block Ice Packed Between Two Rows of Radishes - Stems Facing Outward — August 2-3, 1951
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	72°F.	72°F.	72°F.	72°F.	69°F.	64°F.	88	8:00 a.m.
Bunches in Field	2 hrs.	74°F.	74°F.	74°F.	74°F.	71°F.	67°F.	70	10:00 a.m.
Bunches in Field	3 hrs.	77°F.	77°F.	77°F.	77°F.	76°F.	69°F.	65	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	77°F.	77°F.	78°F.	77°F.	76°F.	69°F.	66	11:30 a.m.
After Icing	4 hrs.	73°F.	72°F.	73°F.	77°F.	74°F.	69°F.	72	12:00 p.m.
In Packing Plant	6 hrs.	65°F.	66°F.	64°F.	79°F.	75°F.	70°F.	70	2:00 p.m.
Wholesale Market	12 hrs.	55°F.	55°F.	55°F.	80°F.	72°F.	67°F.	67	8:00 p.m.
Retail Store	24 hrs.	57°F.	57°F.	56°F.	79°F.	71°F.	66°F.	76	8:00 a.m.

Radishes - Experiment III

In this experiment, the placement of ice was 20 lbs. of block ice packed between the two rows of radishes. The stems of the radishes were arranged so that they faced the ice in the center of the box with the entire pack enclosed in a single paper liner.

The only way in which this experiment differs from Experiment II is the arrangement of the radish leaves. In this experiment, the leaves are facing towards the ice. As might be expected, the difference in the temperatures obtained by using the arrangement in this experiment where the radish leaves faced the ice amounted to only four degrees (Table IT) in each instance, and the condition of the produce upon its arrival at the retail store was approximately the same.

When the radishes reached the retail store, all the ice in the three experimental boxes had melted, but the radish leaves were in excellent condition showing no wilting. In the control box, the radish leaves were completely wilted, and some were becoming slimy.

Radishes - Experiment IV

The placement of ice in this experiment was 20 lbs. of block ice between the two rows of radishes.. The stems of the radishes were so arranged that they faced the ice, and the entire pack was surrounded by a double

Temperature

TABLE TT

Experiment III Radishes - 20 lbs. of Block Ice Packed Between Two Rows - Stems Facing Towards the Ice - Single Paper Liner August 4-5, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Central Crate D	Pkg. Temp.	Air. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	79°F.	80°F.	79°F.	80°F.	78°F.	72°F.	70	9:00 a.m.
Bunches in Field	1 hr.	80°F.	80°F.	80°F.	83°F.	77°F.	74°F.	63	10:00 a.m.
Bunches in Field	2 hrs.	80°F.	82°F.	82°F.	82°F.	79°F.	77°F.	60	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	82°F.	83°F.	82°F.	82°F.	81°F.	77°F.	56	11:30 a.m.
After Icing	3 hrs.	81°F.	82°F.	82°F.	82°F.	80°F.	78°F.	56	12:00 p.m.
In Packing Plant	5 hrs.	68°F.	69°F.	68°F.	83°F.	95°F.	90°F.	54	2:00 p.m.
Wholesale Market	11 hrs.	53°F.	54°F.	53°F.	80°F.	74°F.	70°F.	62	8:00 p.m.
Retail Store	23 hrs.	53°F.	54°F.	53°F.	80°F.	69°F.	65°F.	75	8:00 a.m.

Temperature

TABLE UU

Experiment IV — Radishes - 20 lbs. of Block Ice Packed Between The Two Rows - Double Paper Liner — September 5-6, 1930

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	73°F.	59°F.	90	8:00 a.m.
Bunches in Field	2 hrs.	79°F.	79°F.	79°F.	79°F.	79°F.	74°F.	85	10:00 a.m.
Bunches in Field Boxes	3 hrs.	80°F.	81°F.	82°F.	80°F.	80°F.	78°F.	80	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	81°F.	82°F.	82°F.	80°F.	83°F.	79°F.	80	11:30 a.m.
After Icing	4 hrs.	70°F.	71°F.	79°F.	81°F.	81°F.	80°F.	76	12:00 p.m.
In Packing Plant	6 hrs.	63°F.	62°F.	63°F.	82°F.	88°F.	83°F.	74	2:00 p.m.
Warehouse	12 hrs.	55°F.	55°F.	55°F.	83°F.	73°F.	70°F.	78	8:00 p.m.
Retail Store	24 hrs.	56°F.	53°F.	54°F.	80°F.	71°F.	67°F.	88	8:00 a.m.

paper liner. This method of icing gave satisfactory results with the temperature slowly dropping after icing until the temperature at the retail store the following morning averaged 54°F. (Table UU).

At the retail store, the ice in the experimental boxes had completely melted, but the radish leaves were in excellent condition showing no evidence of wilting. In the control box, however, the radish leaves were completely wilted and some of the leaves had become slimy.

This experiment using a double paper liner was performed in order to see if there was any advantage in using a double paper liner over that of a single paper liner. As the foregoing results would seem to indicate, there is absolutely no advantage in using a double paper liner, or if there were an advantage, it was so small that it could not be detected.

Radishes - Experiment V

In this experiment, the radishes were hydrocooled in an immersion-type hydrocooler (Fig. 12) for five minutes, the water in the hydrocooler having a temperature of 39°F. The radishes were then iced with 20 lbs. of block ice between the rows. The stems were so arranged that they faced outward away from the ice.

This method of hydrocooling and icing produced unsatisfactory results both from a standpoint of maintaining

Temperature

TABLE VV

Experiment V — Radishes - Hydrocooler for 5 Minutes - 20 lbs. of Block Ice Between Two Rows Stems Facing Outward — July 24-25, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	71°F.	71°F.	71°F.	71°F.	67°F.	63°F.	80	8:00 a.m.
Bunches in Field	2 hrs.	76°F.	76°F.	76°F.	76°F.	75°F.	72°F.	66	10:00 a.m.
Bunches in Field Boxes	3 hrs.	77°F.	77°F.	78°F.	77°F.	80°F.	76°F.	50	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	77°F.	78°F.	78°F.	78°F.	81°F.	77°F.	50	11:30 a.m.
After Hydro-cooling and Icing	3 hrs. 40 min.	54°F.	54°F.	53°F.	78°F.	82°F.	77°F.	50	11:40 a.m.
In Packing Plant	4 hrs.	52°F.	55°F.	54°F.	79°F.	74°F.	80°F.	46	12:00 p.m.
Warehouse	12 hrs.	64°F.	65°F.	65°F.	79°F.	73°F.	69°F.	75	8:00 p.m.
Retail Store	24 hrs.	70°F.	72°F.	70°F.	76°F.	74°F.	71°F.	80	8:00 a.m.

a low temperature and preventing deterioration.

Hydrocooling produced an immediate and rapid drop in the temperature of the radishes, but once the temperature was within the protective range, the cooling effect of the ice was not great enough to maintain a low temperature during the remainder of the marketing operation. By the time the radishes arrived at the retail store, the temperature in the experimental boxes averaged 71°F. (Table VV).

At the retail store, the ice in the three experimental boxes had completely melted, and the radishes in all three boxes had severely wilted leaves. In the control box, the radish leaves were completely wilted, and some of the leaves had become slimy.

Radishes - Experiment VI

In this experiment, the radishes were hydrocooled for ten minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler being 54°F., and then iced with 20 lbs. of block ice which was placed between the two rows of radishes. The radishes were arranged so that the stems faced outward away from the ice. Here again, as in the preceding experiment, the temperature produced by this combination of hydrocooling and icing was not low enough to prevent deterioration of the radish leaves. Hydrocooling did bring the temperature down to

Temperature

TABLE WW

Experiment VI Radishes - Hydrocooler for 10 Minutes - 20 lbs. July 26-27, 1950
of Block Ice Between Two Rows - Stems Facing Outward

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	70°F.	79°F.	79°F.	79°F.	77°F.	72°F.	63	9:00 a.m.
Bunches in Field	1 hr.	80°F.	80°F.	80°F.	80°F.	78°F.	74°F.	57	10:00 a.m.
Bunches in Field Boxes	2 hrs.	81°F.	82°F.	82°F.	82°F.	82°F.	76°F.	54	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	82°F.	82°F.	82°F.	82°F.	81°F.	76°F.	52	11:30 a.m.
After Hydro-cooling	2 hrs. 40 min.	51°F.	51°F.	50°F.	83°F.	82°F.	77°F.	52	11:40 a.m.
In Packing Plant	5 hrs.	50°F.	51°F.	49°F.	84°F.	83°F.	78°F.	52	2:00 p.m.
Warehouse	11 hrs.	62°F.	60°F.	59°F.	79°F.	75°F.	70°F.	70	8:00 p.m.
Retail Store	23 hrs.	65°F.	64°F.	63°F.	80°F.	75°F.	67°F.	65	8:00 a.m.

well within the protective range as recommended by Platenius (34) but almost immediately after hydrocooling, the temperature in the iced boxes began to rise until at the retail store, the temperature in the radish boxes averaged 64°F. (Table WW).

At the retail store in the three experimental boxes, the ice had completely melted, and the radish leaves in all three boxes were severely wilted, In the control box, the radish leaves were completely wilted and very slimy.

Radishes - Experiment VII

In this experiment, the radishes were hydrocooled for fifteen minutes in an immersion-type hydrocooler (Fig. 12). The water in the hydrocooler was at a temperature of 42°F. Next, the produce was iced with 20 lbs. of block ice between the two rows of radishes. The radish stems were so arranged that they faced outward away from the ice. This combination of hydrocooling and icing also produced unsatisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration.

It will be noted on Table XX that hydrocooling caused an immediate and rapid decline in the temperature of the radish boxes, but the ice in the pack was unable to maintain this low temperature produced by hydro-

Temperature

TABLE XX

Experiment VII — Radishes - Hydrocooler for 15 Minutes - 20 lbs. of Block Ice Between Two Rows- Stems Facing Outward — July 28-29, 1950

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	81°F.	81°F.	81°F.	81°F.	80°F.	76°F.	68	9:00 a.m.
Bunches in Field	1 hr.	85°F.	85°F.	85°F.	85°F.	84°F.	78°F.	58	10:00 a.m.
Bunches in Field Boxes	2 hrs.	86°F.	86°F.	87°F.	87°F.	85°F.	83°F.	55	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	87°F.	88°F.	88°F.	88°F.	83°F.	84°F.	57	11:30 a.m.
After Hydro-cooling and Icing	3 hrs.	45°F.	46°F.	45°F.	89°F.	83°F.	85°F.	48	12:00 p.m.
In Packing Plant	5 hrs.	47°F.	47°F.	48°F.	89°F.	87°F.	87°F.	45	2:00 p.m.
Warehouse	11 hrs.	53°F.	55°F.	61°F.	88°F.	76°F.	70°F.	75	8:00 p.m.
Retail Store	23 hrs.	56°F.	58°F.	58°F.	86°F.	72°F.	63°F.	84	8:00 a.m.

cooling through the remainder of the marketing operation.

At the retail store, the ice in the three experimental boxes had completely melted by this time, and the radish leaves in the iced boxes had become wilted. In the control box, the radish leaves were all wilted and had become slimy.

Radishes - Experiment VIII

In this experiment, the radishes were hydrocooled for five minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler being at a temperature of 40°F., and then iced with 25 lbs. of No. 1 ice placed between the two rows of radishes. The radish stems were so arranged that they faced outward away from the ice. The only difference in this experiment and Experiment V was the type of ice and the amounts used. In Experiment V, 20 lbs. of block ice was packed between the rows, and in this experiment, 25 lbs. of No. 1 ice was packed in the same manner. Even though the 25 lbs. of No. 1 ice in this experiment did maintain the temperature in the radish boxes at a somewhat lower level, it was not sufficiently low to prevent the radish leaves from wilting.

Hydrocooling caused an immediate and rapid lowering of the temperature, but from the end of hydrocooling until the radishes arrived at the retail store there was a steady increase in temperature. At the re-

Temperature

TABLE XX

Experiment VIII Radishes - Hydrocooler for 5 Minutes - 25 lbs. August 14-15, 1951
of No. 1 Ice Between Rows - Stems Facing Outward

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	76°F.	76°F.	76°F.	76°F.	77°F.	74°F.	70	10:00 a.m.
Bunches in Field	1 hr.	78°F.	79°F.	79°F.	79°F.	81°F.	78°F.	68	11:00 a.m.
In Packing Plant	2 hrs.	82°F.	82°F.	82°F.	82°F.	84°F.	83°F.	66	12:00 p.m.
After Hydro-cooling and Icing	2 hrs. 30 min.	61°F.	62°F.	62°F.	82°F.	82°F.	83°F.	64	12:30 a.m.
In Packing Plant	3 hrs.	57°F.	57°F.	56°F.	83°F.	82°F.	84°F.	64	1:00 p.m.
Warehouse	9 hrs.	51°F.	52°F.	52°F.	87°F.	84°F.	80°F.	67	7:00 p.m.
Retail Store	22 hrs.	64°F.	64°F.	64°F.	80°F.	75°F.	72°F.	80	8:00 a.m.

tail store, the temperature in the experimental boxes averaged 64°F. (Table YY).

By this time, the ice in all three of the experimental boxes had melted, and the temperature had begun to rise. In the three iced boxes, the radish leaves had become completely wilted. In the control box, the radishes were completely wilted and slimy.

Radishes - Experiment IX

In this experiment, the radishes were hydrocooled for ten minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler being at 44°F., and then iced with 65 lbs. of No. 1 ice placed between the rows of radishes. The bunches of radishes were so arranged that the stems of the radishes were facing outward away from the ice.

This combination of hydrocooling and icing produced fairly satisfactory results as will be noted on Table ZZ. Hydrocooling produced an immediate and rapid drop in temperature of the radishes from 82°F. to 52°F. The temperature very slowly and steadily increased after hydrocooling until the radishes reached the retail store, and the amount and placement of ice was sufficient to hold the temperature within the protective temperature range of 55°F. as recommended by Platenius (34).

The ice in the three experimental boxes had

Temperature

TABLE ZZ

Experiment IX — Radishes - Hydrocooler for 10 Minutes - 85 lbs. August 14-15, 1951 of No. 1 Ice Between Rows - Stems Facing Outward

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Lab. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	76°F.	76°F.	76°F.	76°F.	77°F.	74°F.	70	10:00 a.m.
Bunches in Field	1 hr.	79°F.	79°F.	79°F.	79°F.	81°F.	78°F.	68	11:00 a.m.
In Packing Plant	2 hrs.	82°F.	82°F.	82°F.	82°F.	84°F.	83°F.	66	12:00 p.m.
After Hydro-cooling and Icing	2 hrs. 30 min.	53°F.	52°F.	52°F.	82°F.	82°F.	83°F.	64	12:30 p.m.
In Packing Plant	3 hrs.	50°F.	49°F.	50°F.	82°F.	82°F.	84°F.	64	1:00 p.m.
Warehouse	9 hrs.	48°F.	48°F.	49°F.	82°F.	84°F.	80°F.	67	9:00 p.m.
Retail Store	22 hrs.	55°F.	54°F.	54°F.	87°F.	75°F.	72°F.	80	8:00 a.m.

completely melted by the time they had reached the retail store, but the radish leaves were in good condition with only a few of the leaves beginning to wilt. In the control box, the radish leaves were completely wilted, and some of them were becoming slimy.

Radishes - Experiment X

In this experiment, the radishes were hydrocooled for fifteen minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler being at a temperature of 39°F., and then iced with 25 lbs. of No. 1 ice placed between the two rows of radishes. The radish stems were so arranged that they faced outward away from the ice. This method of hydrocooling and icing produced satisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration. The field heat was removed very effectively by hydrocooling, and the amount and placement of ice was sufficient to maintain the temperature of the radishes in the upper 40's and lower 50's during the remainder of the marketing operation (Table AB).

At the retail store, the ice in the three experimental boxes had completely melted, but the radish leaves were only slightly wilted. In the control box, all radish leaves were completely wilted.

Radishes - Experiment XI

In this experiment, the radishes were hydro-

Temperature

TABLE AB

Experiment X — Radishes - Hydrocooler for 15 Minutes - 25 lbs. August 20-21, 1951 of No. 1 Ice Between Rows - Stems Facing Outward

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	61°F.	58°F.	86	8:00 a.m.
Bunches in Field	1 hr.	72°F.	71°F.	72°F.	71°F.	69°F.	63°F.	88	9:00 a.m.
In Packing Plant	2 hrs.	73°F.	73°F.	74°F.	73°F.	69°F.	63°F.	88	10:00 a.m.
After Hydro-cooling and Icing	3 hrs.	48°F.	48°F.	48°F.	75°F.	71°F.	63°F.	88	11:00 a.m.
In Packing Plant	4 hrs.	45°F.	46°F.	47°F.	77°F.	70°F.	68°F.	86	12:00 p.m.
In Packing Plant	5 hrs.	45°F.	47°F.	47°F.	78°F.	70°F.	68°F.	86	1:00 p.m.
Warehouse	9 hrs.	45°F.	46°F.	45°F.	81°F.	74°F.	67°F.	82	5:00 p.m.
Retail Store	24 hrs.	51°F.	49°F.	50°F.	77°F.	66°F.	61°F.	89	8:00 a.m.

Temperature

TABLE AC

Experiment XI — Radishes - Hydrocooler for 5 Minutes - 20 lbs. August 9-10, 1950
of Block Ice Between Two Rows - Stems Facing Outward
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	76°F.	72°F.	74	9:00 a.m.
Bunches in Field	1 hr.	79°F.	79°F.	79°F.	79°F.	81°F.	76°F.	66	10:00 a.m.
Bunches in Field Boxes	2 hrs.	82°F.	82°F.	82°F.	81°F.	84°F.	80°F.	60	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	83°F.	83°F.	83°F.	81°F.	88°F.	82°F.	56	11:30 a.m.
After Hydro-cooling and Icing	3 hrs.	53°F.	51°F.	52°F.	82°F.	86°F.	84°F.	55	12:00 p.m.
In Packing Plant	5 hrs.	49°F.	48°F.	49°F.	83°F.	87°F.	88°F.	45	2:00 p.m.
Warehouse	11 hrs.	48°F.	47°F.	47°F.	85°F.	84°F.	79°F.	66	8:00 p.m.
Retail Store	23 hrs.	50°F.	49°F.	48°F.	85°F.	79°F.	75°F.	89	8:00 a.m.

cooled for five minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler being at a temperature of 40°F., and then iced with 20 lbs. of block ice placed between the two rows of radishes. The stems of the radishes were arranged so that they faced outward away from the ice, and the entire pack was enclosed in a single paper liner. This combination of hydrocooling and icing plus a paper liner produced satisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration. The temperature in the three experimental boxes after hydrocooling and icing was maintained well below the critical temperature of 55°F. as recommended by Platenius (34)--for the most part in the upper 40's and lower 50's (Table AC).

At the retail store, the ice in the three experimental boxes had completely melted, and some of the radish leaves in the upper layers of each box had become slightly wilted. In the control box, on the other hand, all radish leaves were completely wilted, and better than 25% of the leaves had become slimy.

Radishes - Experiment XII

In this experiment, the radishes were hydrocooled for ten minutes in an immersion-type hydrocooler (Fig. 12), the water at a temperature of 37°F., and then iced with 20 lbs. of block ice placed between the two rows of radishes. The stems of the radishes were arranged

Temperature

TABLE AD

Experiment XII Radishes - Hydrocooler for 10 Minutes - 20 lbs. August 30-31, 1930
of Block Ice Between Two Rows - Stems Facing Outward
Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	77°F.	77°F.	77°F.	77°F.	73°F.	69°F.	85	8:00 a.m.
Bunches in Field	2 hrs.	79°F.	79°F.	79°F.	79°F.	76°F.	72°F.	77	10:00 a.m.
Bunches in Field Boxes	3 hrs.	81°F.	82°F.	82°F.	80°F.	79°F.	75°F.	70	11:00 a.m.
In Packing Plant	3 hrs. 30 min.	82°F.	83°F.	82°F.	81°F.	78°F.	76°F.	70	11:30 a.m.
After Hydro-cooling and Icing	4 hrs.	42°F.	42°F.	42°F.	81°F.	80°F.	76°F.	70	12:00 p.m.
In Packing Plant	6 hrs.	42°F.	42°F.	43°F.	83°F.	82°F.	77°F.	69	2:00 p.m.
Warehouse	12 hrs.	45°F.	43°F.	46°F.	81°F.	72°F.	68°F.	77	8:00 p.m.
Retail Stores	24 hrs.	47°F.	45°F.	49°F.	80°F.	70°F.	64°F.	91	8:00 a.m.

so that they faced away from the ice, and the entire pack was enclosed with a single paper liner.

The above combination of hydrocooling and icing produced excellent results both from a standpoint of maintaining a low temperature and preventing deterioration. After hydrocooling and icing, the temperature in the radish boxes was maintained well below the critical temperature of 55°F. as recommended by Platenius (34), for the most part in the lower and upper 40's (Table AD).

At the retail store, the ice in all three of the experimental boxes had melted by this time but the radish leaves were in excellent condition with only a few bunches in each box showing slight amounts of wilting. In the control box, all radish leaves were completely wilted and most of the leaves had become slimy.

Radishes - Experiment XIII

In this experiment, the radishes were hydrocooled for fifteen minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler was at a temperature of 42°F., and then iced with 20 lbs. of block ice placed between the two rows of radishes. The radish stems were so arranged that they faced away from the ice, and the entire pack was enclosed in a single paper liner.

The only way in which this experiment differed from the preceding experiment was the length of time the

Temperature

TABLE AE

Experiment XIII — Radishes - Hydrocooler for 15 Minutes — September 1-2, 1950
20 lbs. of Block Ice Between Two Rows - Stems Facing Outward - Single Paper Liner

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exc.
Harvest Time	0 hrs.	82°F.	82°F.	82°F.	82°F.	79°F.	75°F.	96	9:00 a.m.
Bunches in Field	1 hr.	84°F.	84°F.	84°F.	84°F.	80°F.	76°F.	96	10:00 a.m.
Bunches in Field Boxes	2 hrs.	87°F.	86°F.	88°F.	87°F.	83°F.	80°F.	96	11:00 a.m.
In Packing Plant	2 hrs. 30 min.	87°F.	87°F.	88°F.	88°F.	85°F.	82°F.	90	11:30 a.m.
After hydro-cooling and Icing	3 hrs.	41°F.	42°F.	41°F.	87°F.	87°F.	84°F.	80	12:00 p.m.
In Packing Plant	5 hrs.	42°F.	43°F.	42°F.	87°F.	84°F.	76°F.	91	2:00 p.m.
Warehouse	11 hrs.	43°F.	44°F.	44°F.	85°F.	78°F.	74°F.	94	8:00 p.m.
Retail Store	23 hrs.	47°F.	44°F.	45°F.	82°F.	75°F.	68°F.	98	8:00 a.m.

produce was subjected to hydrocooling. In this experiment, the radishes were hydrocooled for fifteen minutes instead of ten minutes. The results were pretty much the same with the temperature being maintained in the lower 40's after hydrocooling and icing, and an excellent pack arrived at the retail store.

At the retail store, the ice in the three experimental boxes had completely melted by this time, and the temperature had begun to rise. The radish leaves in the three experimental boxes were in excellent condition showing no signs of wilting. In the control box, however, the radish leaves were completely wilted, and most all of them had become very slimy.

Radishes - Experiment XIV

In this experiment, the radishes were hydrocooled for five minutes in an immersion-type hydrocooler (Fig. 12) and then iced with 25 lbs. of No. 1 ice placed between the rows of radishes. The radish stems were so arranged that they faced outward away from the ice, and the entire pack was enclosed in a single paper liner.

Here again, 25 lbs. of No. 1 ice was packed between the two rows of radishes instead of 20 lbs. of block ice.

If a comparison is made between Experiment XI and this experiment, it will be found that the use of

Temperature

TABLE AF

Experiment XIV — Radishes - Hydrocooler for 5 Minutes - Stems Facing Outward - 25 lbs. of No. 1 Ice Between Rows Single Paper Liner — August 20-21, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	64°F.	64°F.	64°F.	64°F.	62°F.	58°F.	86	8:00 a.m.
Bunches in Field	1 hr.	71°F.	72°F.	72°F.	71°F.	69°F.	63°F.	88	9:00 a.m.
In Packing Plant	2 hrs.	73°F.	74°F.	73°F.	73°F.	69°F.	63°F.	88	10:00 a.m.
After Hydro-cooling and Icing	3 hrs.	48°F.	48°F.	49°F.	75°F.	71°F.	63°F.	88	11:00 a.m.
In Packing Plant	4 hrs.	46°F.	45°F.	46°F.	77°F.	70°F.	68°F.	86	12:00 p.m.
In Packing Plant	5 hrs.	45°F.	45°F.	44°F.	79°F.	70°F.	68°F.	86	1:00 p.m.
Warehouse	9 hrs.	44°F.	43°F.	43°F.	81°F.	74°F.	67°F.	82	5:00 p.m.
Retail Store	24 hrs.	48°F.	48°F.	49°F.	77°F.	66°F.	61°F.	89	8:00 a.m.

25 lbs. of No. 1 ice produced results which were very similar to those obtained by the use of 20 lbs. of block ice. The temperatures throughout the marketing operation were within one or two degrees of one another (Table AF), and the end results were the same resulting in an excellent pack upon arrival at the retail store.

At the retail store the ice had completely melted in all three experimental boxes by this time, but the radish leaves were in good condition showing only slight wilting of the leaves in the upper layers. In the control box, however, the radish leaves were completely wilted.

Radishes - Experiment XV

In this experiment, the radishes were hydrocooled for ten minutes in an immersion-type hydrocooler (Fig. 12), the water at a temperature of 40°F., and then iced with 25 lbs. of No. 1 ice placed between the two rows of radishes. The radish stems were so arranged that they faced outward away from the ice, and the entire pack was enclosed in a single paper liner.

This combination of icing and hydrocooling produced satisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration.

After hydrocooling and icing, the temperatures in the experimental boxes were held down in the upper 40's

Temperature

TABLE AG

Experiment XV — Radishes - Hydrocooler for 10 Minutes - Stems Facing Outward - 25 lbs. of No. 1 Ice Between Rows Single Paper Liner — August 27-28, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	73°F.	73°F.	73°F.	73°F.	74°F.	72°F.	77	10:00 a.m.
Bunches in Field	1 hr.	80°F.	80°F.	79°F.	80°F.	78°F.	74°F.	75	11:00 a.m.
In Packing Plant	2 hrs.	83°F.	83°F.	83°F.	83°F.	79°F.	73°F.	76	12:00 p.m.
After Hydro-cooling and Icing	2 hrs. 30 min.	55°F.	55°F.	56°F.	85°F.	79°F.	73°F.	76	12:30 p.m.
In Packing Plant	3 hrs.	50°F.	49°F.	51°F.	85°F.	79°F.	73°F.	76	1:00 p.m.
Warehouse	7 hrs.	47°F.	47°F.	47°F.	87°F.	78°F.	75°F.	69	5:00 p.m.
Retail Store	22 hrs.	50°F.	50°F.	49°F.	76°F.	67°F.	64°F.	87	8:00 a.m.

and lower 50's. The average temperature in the radish boxes upon their arrival at the retail store was 50°F. (Table AG).

At the retail store, the ice in the three experimental boxes had completely melted by this time, and a slight wilting of all radish leaves had taken place. In the control box, the radish leaves were completely wilted, and some of them had become slimy.

Radishes - Experiment XVI

In this experiment, the radishes were hydrocooled for fifteen minutes in an immersion-type hydrocooler (Fig. 12), the water in the hydrocooler having a temperature of 39°F., and then iced with 25 lbs. of No. 1 ice placed between the two rows of radishes. The radish stems were so arranged that they faced outward away from the ice, and the entire pack was enclosed in a single paper liner.

This method of hydrocooling and icing produced satisfactory results both from a standpoint of maintaining a low temperature and preventing deterioration.

After hydrocooling and icing, the temperatures in the three experimental boxes were held well below the critical temperature of 55°F. as recommended by Platenius (34)--for the most part in the upper 40's and lower 50's.

At the retail store, the ice in the three

Temperature

TABLE XII

Experiment XVI — Radishes - Hydrocooler for 15 Minutes - Stems Facing Outward - 25 lbs. of Ice Between Row - Single Paper Liner — August 27-28, 1951

Place of Experiment	Time From Harvest	Crate A	Crate B	Crate C	Control Crate D	Amb. Temp.	Atm. Temp.	R.H.	Time of Exp.
Harvest Time	0 hrs.	73°F.	73°F.	73°F.	73°F.	74°F.	73°F.	77	10:00 a.m.
Bunches in Field	1 hr.	80°F.	80°F.	79°F.	80°F.	78°F.	74°F.	75	11:00 a.m.
In Packing Plant	2 hrs.	83°F.	82°F.	83°F.	84°F.	79°F.	73°F.	76	12:00 p.m.
After Hydro-cooling and Icing	2 hrs. 30 min.	55°F.	54°F.	55°F.	85°F.	79°F.	73°F.	76	12:30 p.m.
In Packing Plant	3 hrs.	50°F.	50°F.	51°F.	85°F.	79°F.	73°F.	76	1:00 p.m.
Warehouse	7 hrs.	47°F.	48°F.	47°F.	87°F.	78°F.	75°F.	69	5:00 p.m.
Retail Store	22 hrs.	50°F.	49°F.	49°F.	76°F.	67°F.	64°F.	87	8:00 a.m.

experimental boxes had completely melted by this time, but the radish leaves were in good condition with only slight wilting of the leaves in the upper layers. In the control box, the radish leaves had become completely wilted and slimy.

Asparagus

Controlled Retail Experiment I

This experiment was carried out in the laboratory at the University of Massachusetts on July 4 and 5, 1950. The experiment was conducted in an ice display case very similar to those used in retail stores (Fig. 16). The object of the experiment was to determine the temperature of asparagus under retail conditions when packed in crushed ice so that the bunches were completely covered in 4 ins. of ice, in 2 ins. of ice, resting on ice, in tap water and packed dry. In each of the above methods where ice was used, grades of ice 1 through 5 were tested on each method. Each test was repeated five times for each grade of ice and five times for tap water and dry packed. In each test, 1-lb. bunches of asparagus were used, and the temperature was recorded by inserting a thermometer in the center of the bunch.

Asparagus was harvested between 6:00 a.m. and 8:00 a.m. on the morning of July 4, 1950. After bunching and trimming on the grower's farm, the asparagus was

transported to the laboratory in French Hall at the University of Massachusetts. At 4:00 p.m., the experiment began and ran until 4:00 a.m. on the morning of July 5, 1950, a period of twelve hours. During the twelve-hour period, temperature recordings were made hourly.

Within two hours from the beginning of the experiment, the asparagus completely covered with ice of all grades, the asparagus packed in 4 ins. of ice of all grades, and the asparagus packed in 2 ins. of ice of all grades were below the protective temperature of 55°F. as recommended by Platenius (34) at the end of twelve hours. The lowest temperature attained at the end of twelve hours by asparagus completely packed in No. 1 ice was 31°F.; No. 2 ice, 31°F.; No. 3 ice, 32°F.; No. 4 ice, 34°F.; No. 5 ice, 32°F. (Table AI). The lowest temperature attained at the end of twelve hours by asparagus packed in 4 ins. of No. 1 ice was 33°F.; No. 2 ice, 34°F.; No. 3 ice, 36°F.; No. 4 ice, 32°F. and No. 5 ice, 41°F. (Table AJ). The lowest temperature attained at the end of twelve hours by asparagus packed in 2 ins. of No. 1 ice was 45°F.; No. 2 ice, 38°F.; No. 3 ice, 41°F.; No. 4 ice, 38°F. and No. 5 ice, 42°F. (Table AK).

The last of the iced asparagus to come within a protective temperature range were those resting on ice.

Temperatures

TABLE AI

Retail Experiment I — Asparagus - Completely Covered with Ice — July 4-5, 1950

Place of Experiment	Time From Beginning of Exp.	No. 1 Ice	No. 2 Ice	No. 3 Ice	No. 4 Ice	No. 5 Ice	R.H.	Amb. Temp.	Atm. Temp.	Time of Exp.
U. of M. Laboratory	0 min.	77°F.	77°F.	78°F.	79°F.	78°F.	90	74°F.	70°F.	4:00 p.m.
U. of M. Laboratory	15 min.	68°F.	72°F.	75°F.	77°F.	76°F.	90	73°F.	70°F.	4:15 p.m.
U. of M. Laboratory	30 min.	57°F.	65°F.	69°F.	72°F.	70°F.	90	72°F.	70°F.	4:30 p.m.
U. of M. Laboratory	45 min.	53°F.	58°F.	62°F.	65°F.	64°F.	90	71°F.	70°F.	4:45 p.m.
U. of M. Laboratory	1 hr.	48°F.	53°F.	54°F.	58°F.	57°F.	90	71°F.	70°F.	5:00 p.m.
U. of M. Laboratory	2 hrs.	37°F.	40°F.	40°F.	40°F.	40°F.	90	71°F.	71°F.	6:00 p.m.
U. of M. Laboratory	3 hrs.	33°F.	36°F.	37°F.	39°F.	37°F.	90	71°F.	71°F.	7:00 p.m.
U. of M. Laboratory	4 hrs.	31°F.	33°F.	33°F.	35°F.	34°F.	93	73°F.	69°F.	8:00 p.m.
U. of M. Laboratory	5 hrs.	31°F.	32°F.	32°F.	32°F.	33°F.	94	73°F.	68°F.	9:00 p.m.
U. of M. Laboratory	6 hrs.	31°F.	31°F.	32°F.	32°F.	33°F.	94	73°F.	67°F.	10:00 p.m.
U. of M. Laboratory	7 hrs.	31°F.	31°F.	32°F.	32°F.	33°F.	94	73°F.	65°F.	11:00 p.m.

Temperature

TABLE AI - continued

Retail Experiment I — Asparagus - Completely Covered with Ice — July 4-5, 1950

U. of M. Laboratory	8 hrs.	31°F.	31°F.	32°F.	34°F.	33°F.	94	73°F.	64°F.	12:00 p.m.
U. of M. Laboratory	9 hrs.	31°F.	31°F.	32°F.	34°F.	33°F.	94	72°F.	63°F.	1:00 a.m.
U. of M. Laboratory	10 hrs.	31°F.	31°F.	32°F.	34°F.	33°F.	94	72°F.	63°F.	2:00 a.m.
U. of M. Laboratory	11 hrs.	31°F.	31°F.	32°F.	34°F.	33°F.	94	72°F.	62°F.	3:00 a.m.
U. of M. Laboratory	12 hrs.	31°F.	31°F.	32°F.	34°F.	33°F.	94	72°F.	62°F.	4:00 a.m.

Temperature

TABLE AJ

Retail Experiment I — Asparagus - In 4 Ins. of Ice — July 4-5, 1950

Place of Experiment	Time From Beginning of Exp.	No. 1 Ice	No. 2 Ice	No. 3 Ice	No. 4 Ice	No. 5 Ice	R.H.	Amb. Temp.	Atm. Temp.	Time of Exp.
U. of M. Laboratory	0 min.	78°F.	78°F.	81°F.	75°F.	80°F.	90	74°F.	70°F.	4:00 p.m.
U. of M. Laboratory	15 min.	73°F.	71°F.	71°F.	73°F.	79°F.	90	73°F.	70°F.	4:15 p.m.
U. of M. Laboratory	30 min.	65°F.	64°F.	71°F.	68°F.	76°F.	90	72°F.	70°F.	4:30 p.m.
U. of M. Laboratory	45 min.	58°F.	57°F.	75°F.	63°F.	71°F.	90	71°F.	70°F.	4:45 p.m.
U. of M. Laboratory	1 hr.	52°F.	52°F.	59°F.	58°F.	67°F.	90	71°F.	70°F.	5:00 p.m.

Temperature

TABLE AJ - continued

Retail Experiment I — Asparagus - In 4 Ins. of Ice — July 4-5, 1950

U. of M. Laboratory	2 hrs.	39°F.	40°F.	48°F.	57°F.	54°F.	90	71°F.	71°F.	6:00 p.m.
U. of M. Laboratory	3 hrs.	36°F.	37°F.	48°F.	54°F.	50°F.	90	71°F.	71°F.	7:00 p.m.
U. of M. Laboratory	4 hrs.	34°F.	34°F.	46°F.	44°F.	48°F.	93	73°F.	69°F.	8:00 p.m.
U. of M. Laboratory	5 hrs.	33°F.	32°F.	39°F.	35°F.	48°F.	94	73°F.	68°F.	9:00 p.m.
U. of M. Laboratory	6 hrs.	33°F.	34°F.	37°F.	32°F.	48°F.	94	73°F.	67°F.	10:00 p.m.
U. of M. Laboratory	7 hrs.	33°F.	32°F.	34°F.	32°F.	45°F.	74	73°F.	65°F.	11:00 p.m.
U. of M. Laboratory	8 hrs.	33°F.	34°F.	36°F.	32°F.	41°F.	94	73°F.	64°F.	12:00 a.m.
U. of M. Laboratory	9 hrs.	33°F.	34°F.	36°F.	32°F.	44°F.	94	72°F.	63°F.	1:00 a.m.
U. of M. Laboratory	10 hrs.	33°F.	34°F.	38°F.	32°F.	45°F.	94	72°F.	63°F.	2:00 a.m.
U. of M. Laboratory	11 hrs.	33°F.	34°F.	36°F.	32°F.	41°F.	74	72°F.	62°F.	3:00 a.m.
U. of M. Laboratory	12 hrs.	33°F.	34°F.	36°F.	32°F.	41°F.	94	72°F.	62°F.	4:00 a.m.

Temperature

TABLE AK

Retail Experiment I — Asparagus - In 2 Ins. of Ice — July 4-5, 1950

Place of Experiment	Time From Beginning of Exp.	No. 1 Ice	No. 2 Ice	No. 3 Ice	No. 4 Ice	No. 5 Ice	R.H.	Amb. Temp.	Atm. Temp.	Time of Exp.
U. of M. Laboratory	0 min.	79°F.	78°F.	79°F.	80°F.	77°F.	90	74°F.	70°F.	4:00 p.m.
U. of M. Laboratory	15 min.	74°F.	73°F.	75°F.	77°F.	77°F.	90	73°F.	70°F.	4:15 p.m.
U. of M. Laboratory	30 min.	67°F.	71°F.	71°F.	72°F.	73°F.	90	72°F.	70°F.	4:30 p.m.
U. of M. Laboratory	45 min.	63°F.	66°F.	68°F.	67°F.	68°F.	90	71°F.	70°F.	4:45 p.m.
U. of M. Laboratory	1 hr.	61°F.	60°F.	60°F.	63°F.	66°F.	90	71°F.	70°F.	5:00 p.m.
U. of M. Laboratory	2 hrs.	49°F.	54°F.	50°F.	51°F.	54°F.	90	71°F.	71°F.	6:00 p.m.
U. of M. Laboratory	3 hrs.	44°F.	48°F.	42°F.	47°F.	52°F.	90	71°F.	71°F.	7:00 p.m.
U. of M. Laboratory	4 hrs.	41°F.	41°F.	41°F.	41°F.	45°F.	93	73°F.	69°F.	8:00 p.m.
U. of M. Laboratory	5 hrs.	39°F.	41°F.	41°F.	41°F.	43°F.	94	73°F.	68°F.	9:00 p.m.
U. of M. Laboratory	6 hrs.	37°F.	45°F.	41°F.	39°F.	43°F.	94	73°F.	67°F.	10:00 p.m.
U. of M. Laboratory	7 hrs.	38°F.	37°F.	42°F.	36°F.	43°F.	94	74°F.	65°F.	11:00 p.m.

Temperature

TABLE AK - continued

Retail Experiment I — Asparagus - In 2 Ins. of Ice — July 4-5, 1950

U. of M. Laboratory	8 hrs.	45°F.	43°F.	50°F.	38°F.	43°F.	94	72°F.	64°F.	12:00 p.m.
U. of M. Laboratory	9 hrs.	45°F.	40°F.	47°F.	38°F.	42°F.	94	72°F.	63°F.	1:00 a.m.
U. of M. Laboratory	10 hrs.	45°F.	38°F.	41°F.	38°F.	42°F.	94	72°F.	63°F.	2:00 a.m.
U. of M. Laboratory	11 hrs.	45°F.	38°F.	41°F.	38°F.	42°F.	94	72°F.	62°F.	3:00 a.m.
U. of M. Laboratory	12 hrs.	45°F.	38°F.	41°F.	38°F.	42°F.	94	72°F.	62°F.	4:00 a.m.

Temperature

TABLE AL

Retail Experiment I — Asparagus - Resting on Ice — July 4-5, 1950

Place of Experiment	Time From Beginning of Exp.	No. 1 Ice	No. 2 Ice	No. 3 Ice	No. 4 Ice	No. 5 Ice	R.H.	Amb. Temp.	Atm. Temp.	Time of Exp.
U. of M. Laboratory	0 min.	79°F.	82°F.	81°F.	77°F.	79°F.	90	74°F.	70°F.	4:00 p.m.
U. of M. Laboratory	15 min.	76°F.	78°F.	78°F.	77°F.	77°F.	90	73°F.	70°F.	4:15 p.m.
U. of M. Laboratory	30 min.	74°F.	70°F.	73°F.	75°F.	76°F.	90	72°F.	70°F.	4:30 p.m.
U. of M. Laboratory	45 min.	74°F.	66°F.	72°F.	75°F.	73°F.	90	71°F.	70°F.	4:45 p.m.
U. of M. Laboratory	1 hr.	70°F.	66°F.	70°F.	71°F.	72°F.	90	71°F.	70°F.	5:00 p.m.

Temperature

TABLE AL - continued

Retail Experiment I — Ascarsrus - Resting on Ice — July 4-5, 1950

U. of M. Laboratory	2 hrs.	65°F.	60°F.	64°F.	65°F.	67°F.	90	71°F.	71°F.	6:00 p.m.
U. of M. Laboratory	3 hrs.	61°F.	54°F.	59°F.	43°F.	68°F.	90	71°F.	71°F.	7:00 p.m.
U. of M. Laboratory	4 hrs.	57°F.	49°F.	55°F.	40°F.	53°F.	93	73°F.	69°F.	8:00 p.m.
U. of M. Laboratory	5 hrs.	55°F.	55°F.	55°F.	45°F.	58°F.	94	73°F.	68°F.	9:00 p.m.
U. of M. Laboratory	6 hrs.	52°F.	48°F.	55°F.	45°F.	58°F.	94	73°F.	67°F.	10:00 p.m.
U. of M. Laboratory	7 hrs.	55°F.	47°F.	58°F.	48°F.	61°F.	94	73°F.	65°F.	11:00 p.m.
U. of M. Laboratory	8 hrs.	52°F.	46°F.	55°F.	48°F.	58°F.	94	73°F.	64°F.	12:00 a.m.
U. of M. Laboratory	9 hrs.	51°F.	46°F.	55°F.	48°F.	56°F.	94	72°F.	63°F.	1:00 a.m.
U. of M. Laboratory	10 hrs.	51°F.	46°F.	55°F.	48°F.	55°F.	94	72°F.	63°F.	2:00 a.m.
U. of M. Laboratory	11 hrs.	51°F.	46°F.	55°F.	48°F.	55°F.	94	72°F.	62°F.	3:00 a.m.
U. of M. Laboratory	12 hrs.	51°F.	46°F.	55°F.	48°F.	55°F.	94	72°F.	62°F.	4:00 a.m.

Temperature

TABLE AM

Retail Experiment I Asparagus - Dry and In 1/2 In. of Tap Water July 4-5, 1950

Place of Experiment	Time From Beginning of Exp.	Tap Water	Dry	R.H.	Amb. Temp.	Atm. Temp.	Time of Exp.
U. of M. Laboratory	0 min.	77°F.	79°F.	90	74°F.	70°F.	4:00 p.m.
U. of M. Laboratory	15 min.	74°F.	77°F.	90	73°F.	70°F.	4:15 p.m.
U. of M. Laboratory	30 min.	74°F.	77°F.	90	72°F.	70°F.	4:30 p.m.
U. of M. Laboratory	45 min.	75°F.	76°F.	90	71°F.	70°F.	4:45 p.m.
U. of M. Laboratory	1 hr.	73°F.	75°F.	90	71°F.	70°F.	5:00 p.m.
U. of M. Laboratory	2 hrs.	72°F.	72°F.	90	71°F.	71°F.	6:00 p.m.
U. of M. Laboratory	3 hrs.	69°F.	71°F.	93	71°F.	71°F.	7:00 p.m.
U. of M. Laboratory	4 hrs.	68°F.	66°F.	94	73°F.	69°F.	8:00 p.m.
U. of M. Laboratory	5 hrs.	69°F.	66°F.	94	73°F.	68°F.	9:00 p.m.
U. of M. Laboratory	6 hrs.	69°F.	66°F.	94	73°F.	67°F.	10:00 p.m.
U. of M. Laboratory	7 hrs.	69°F.	68°F.	94	73°F.	65°F.	11:00 p.m.

Temperature

TABLE AM - continued

Retail Experiment I	Asparagus - Dry and In 1/2 In. of Tap Water					July 4-5, 1950	
U. of M. Laboratory	8 hrs.	68°F.	67°F.	94	73°F.	64°F.	12:00 a.m.
U. of M. Laboratory	9 hrs.	69°F.	66°F.	94	72°F.	63°F.	1:00 a.m.
U. of M. Laboratory	10 hrs.	67°F.	65°F.	94	72°F.	63°F.	2:00 a.m.
U. of M. Laboratory	11 hrs.	68°F.	65°F.	94	72°F.	62°F.	3:00 a.m.
U. of M. Laboratory	12 hrs.	68°F.	64°F.	94	72°F.	62°F.	4:00 a.m.

It took nine hours for the temperature of the asparagus resting on all grades of ice to drop below the protective temperature of 55°F. as recommended by Platenius (34). The lowest temperature attained at the end of twelve hours by the asparagus resting on No. 1 ice was 51°F.; No. 2 ice, 46°F.; No. 3 ice, 54°F.; No. 4 ice, 47°F. and No. 5 ice, 54°F. (Table AL).

The asparagus packed in tap water and packed dry attained a temperature below that of the recommended protective temperature of 55°F. during the twelve hours of the experiment (Table AM).

Asparagus

Controlled Retail Experiment II

This experiment was performed in the laboratory at the University of Massachusetts. It ran continuously from June 11 to June 16, 1951, a period of six days. The experiment was conducted in an ice display case very similar to those used in retail stores (Fig. 16). The object of the experiment was to determine the condition of bunched asparagus stored under retail conditions for a period of five days when packed in crushed ice so that the bunches were completely covered, in 4 ins. of ice, in 2 ins. of ice, resting on ice, in tap water and packed dry. In each of the above methods where ice was

used, grade No. 1 was employed, this grade being the size usually used by retail stores.

Each test was repeated five times and five times for tap water and the dry pack. In each test, a 1-lb. bunch of asparagus was used, and the weight, color, amount of feathering of the asparagus heads and the fibrousness of the produce was checked and recorded twice daily at 6:00 a.m. and 7:00 p.m. Methods used to make the above-mentioned tests are described in detail in MATERIALS AND METHODS.

Over a period of five days, the bunched asparagus stored in all depths of ice gained in weight. The maximum gain in weight took place in those completely covered with ice, and the minimum gain in those bunches just resting on the ice. Asparagus stored in 2 ins. of tap water had the largest gain in weight of any of the bunches in the experiment. Those which were not stored in either ice or tap water but simply packed dry, lost in weight (Table AN).

There was a decline in the green color of all the bunches of asparagus packed in ice, tap water, and packed dry. The decline in color was more gradual in ice and tap water in contrast to a very sharp decline in the dry pack (Table AO).

The amount of feathering of the asparagus heads

Table AN

Weight

ASPARAGUS

Experiment II- Controlled No. 2 Ice Used June 11-16, 1951
Retail Counter

Place and Date of Experiment	Time From Harvest	Tips Just Above Ice	Packed In 4 Ins. of Ice	Packed In 2 Ins. of Ice	Butts On Ice	Butts In 2 Ins. of Water	Dry-No Water Or Ice	Time of Reading
Monday June 11, 1951 U. of M. Lab	0 hrs.	1 lb.	1 lb.	1 lb.	1 lb.	1 lb.	1 lb.	7:00 p.m.
Tuesday June 12, 1951 U. of M. Lab	11 hrs.	1 lb. 1 oz.	1 lb.	1 lb.	1 lb.	1 lb. 3 ozs.	1 lb.	6:00 a.m.
Tuesday June 12, 1951 U. of M. Lab	24 hrs.	1 lb. 3 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 2 ozs.	1 lb. 5 ozs.	15 ozs.	7:00 p.m.
Wednesday June 13, 1951 U. of M. Lab	35 hrs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 5 ozs.	14 ozs.	6:00 a.m.
Wednesday June 13, 1951 U. of M. Lab	48 hrs.	1 lb. 4 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 6 ozs.	14 ozs.	7:00 p.m.
Thursday June 14, 1951 U. of M. Lab	59 hrs.	1 lb. 2 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 3 ozs.	1 lb. 6 ozs.	12 ozs.	6:00 a.m.
Thursday June 14, 1951 U. of M. Lab	72 hrs.	1 lb. 3 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 6 ozs.	11 ozs.	7:00 p.m.

Weight

Experiment II- Controlled (continued) June 11-16, 1951
Retail Counter

Friday June 15, 1951 U. of M. Lab	83 hrs.	1 lb. 3 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 8 ozs.	10 ozs.	6:00 a.m.
Friday June 15, 1951 U. of M. Lab	96 hrs.	1 lb. 4 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 8 ozs.		7:00 p.m.
Saturday June 16, 1951 U. of M. Lab	107 hrs.	1 lb. 4 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 8 ozs.		6:00 a.m.
Saturday June 16, 1951 U. of M. Lab	120 hrs.	1 lb. 4 ozs.	1 lb. 4 ozs.	1 lb. 3 ozs.	1 lb. 2 ozs.	1 lb. 8 ozs.		7:00 a.m.

Table AO

Color

ASPARAGUS

Experiment II- Controlled No. 2 Ice Used June 11-16, 1951
Retail Counter

Place and Date of Experiment	Time From Harvest	Tips Just Above Ice	Packed In 4 Ins. of Ice	Packed In 2 Ins. of Ice	Butts On Ice	Butts In 2 Ins. of Water	Dry-No Water Or Ice	Time of Reading
Monday June 11, 1951 U. of M. Lab	0 hrs.	1	2	1	1	1	1	7:00 p.m.
Tuesday June 12, 1951 U. of M. Lab	11 hrs.	1	2	2	2	2	2	6:00 a.m.
Tuesday June 12, 1951 U. of M. Lab	24 hrs.	1	3	3	3	2	2	7:00 p.m.
Wednesday June 13, 1951 U. of M. Lab	35 hrs.	1	3	3	3	3	3	6:00 a.m.
Wednesday June 13, 1951 U. of M. Lab	48 hrs.	1	3	3	3	3	4	7:00 p.m.
Thursday June 14, 1951 U. of M. Lab	59 hrs.	2	3	4	3	3	4	6:00 a.m.
Thursday June 14, 1951 U. of M. Lab	72 hrs.	2	4	4	4	3	4	7:00 p.m.

Experiment II- Controlled Retail Counter — June 11-16, 1951

Friday June 15, 1951 U. of M. Lab	83 hrs.	2	4	4	4	4	5	6:00 a.m.
Friday June 15, 1951 U. of M. Lab	96 hrs.	2	4	4	4	4	5	7:00 p.m.
Saturday June 16, 1951 U. of M. Lab	107 hrs.	2	4	4	4	4		6:00 a.m.
Saturday June 16, 1951 U. of M. Lab	120 hrs.	2	4	4	4	4		7:00 p.m.

Table AP

Amount of Feathering

ASPARAGUS

Experiment II- Controlled Retail Counter

No. 2 Ice Used

June 11-16, 1951

Place and Date of Experiment	Time From Harvest	Tips Just Above Ice	Packed In 4 Ins. of Ice	Packed In 2 Ins. of Ice	Butts On Ice	Butts In 2 Ins. of Water	Dry-No Water Or Ice	Time of Reading
Monday June 11, 1951 U. of M. Lab	0 hrs.	1	1	1	1	2	1	7:00 p.m.
Tuesday June 12, 1951 U. of M. Lab	11 hrs.	1	2	1	1	2	1	6:00 a.m.
Tuesday June 12, 1951 U. of M. Lab	24 hrs.	1	2	1	1	2	1	7:00 p.m.
Wednesday June 13, 1951 U. of M. Lab	35 hrs.	1	2	1	1	2	1	6:00 a.m.
Wednesday June 13, 1951 U. of M. Lab	48 hrs.	1	2	1	1	2	1	7:00 p.m.
Thursday June 14, 1951 U. of M. Lab	59 hrs.	1	2	1	1	2	1	6:00 a.m.
Thursday June 14, 1951 U. of M. Lab	72 hrs.	1	2	1	1	2	1	7:00 p.m.

Amount of Feathering (continued)

Experiment I1- Controlled Retail Counter — June 11-16, 1951

Friday June 15, 1951 U. of M. Lab	83 hrs.	1	2	1	1	2	1	6:00 a.m.
Friday June 15, 1951 U. of M. Lab	96 hrs.	1	2	1	1	2	1	7:00 p.m.
Saturday June 16, 1951 U. of M. Lab	107 hrs.	1	2	1	1	2	1	6:00 a.m.
Saturday June 16, 1951 U. of M. Lab	120 hrs.	1	2	1	1	2	1	7:00 p.m.

Table AQ

Cutting Test

ASPARAGUS

Experiment II- Controlled No. 2 Ice Used June 11-16, 1951
Retail Counter

Place and Date of Experiment	Time From Harvest	Tips Just Above Ice	Packed In 4 Ins. of Ice	Packed In 2 Ins. of Ice	Butts On Ice	Butts In 2 Ins. of Water	Dry-No. Water Or Ice	Time of Reading
Monday June 11, 1951 U. of M. Lab	0 hrs.	380	410	380	400	410	400	7:00 p.m.
Tuesday June 12, 1951 U. of M. Lab	11 hrs.	380	410	380	420	410	400	6:00 a.m.
Tuesday June 12, 1951 U. of M. Lab	24 hrs.	380	410	420	420	410	420	7:00 p.m.
Wednesday June 13, 1951 U. of M. Lab	35 hrs.	400	430	430	430	420	440	6:00 a.m.
Wednesday June 13, 1951 U. of M. Lab	48 hrs.	400	430	430	430	420	440	7:00 p.m.
Thursday June 14, 1951 U. of M. Lab	59 hrs.	420	440	430	450	420	460	6:00 a.m.
Thursday June 14, 1951 U. of M. Lab	72 hrs.	420	440	460	450	420	460	7:00 p.m.

Cutting Test (continued)

Experiment II- Controlled Retail Counter — June 11-16, 1951

Friday June 15, 1951 U. of M. Lab	83 hrs.	420	440	460	460	440	480	6:00 a.m.
Friday June 15, 1951 U. of M. Lab	96 hrs.	420	440	480	480	430		7:00 p.m.
Saturday June 16, 1951 U. of M. Lab	107 hrs.	420	460	480		430		6:00 a.m.
Saturday June 16, 1951 U. of M. Lab	120 hrs.	420	460	480		430		7:00 p.m.

remained unchanged throughout the entire experiment under all storage conditions (Table AP).

There was an increase in the toughness of the asparagus spears under all storage conditions of the experiment. The largest increase noted on those bunches was on those packed dry, and the smallest increase on those bunches packed in 2 ins. of tap water (Table AQ).

DISCUSSION AND SUMMARY

Experiments are described in which precooling and/or icing was used to maintain a low temperature in vegetable packages during the normal marketing operation. Varying lengths of precooling and amounts of ice were used in containers. This was done to determine the optimum length of precooling and amounts of ice necessary to refrigerate specific vegetables during short hauls to market. A crate which received no treatment was included in each experiment as a control.

Asparagus, lettuce, celery and radishes were packed in containers which are commonly used for these crops in local Massachusetts markets except when the method of icing or amounts of ice deemed it necessary to make changes in the containers.

Package histories were recorded at four farms, in two retail store warehouses, one wholesale market and

in eight retail stores. Packages moved through the normal market channels. The speed with which package temperatures were reduced was noted in asparagus, lettuce, celery and radishes. With asparagus in addition to temperature recordings, color, and amount of feathering of the asparagus heads, toughness of the spears was also noted and recorded. The period of time that refrigeration was effective was also recorded for the above-mentioned vegetables. Control retail experiments were conducted at the laboratory of the University of Massachusetts. Retail experiments were set up in two large supermarkets to test consumers' preference of asparagus packed in ice.

Asparagus, lettuce, celery and radish precooling experiments were conducted on an overhead-drain type of hydrocooler and an immersion-type hydrocooler. Refrigerating efficiencies of these two types of precoolers are discussed.

On the basis of experimental data, it was found that under market conditions, top icing asparagus with 10 lbs. of No. 2 ice produced satisfactory results both from a standpoint of maintaining a lower temperature and preventing deterioration. Using the same amounts and sizes of ice but changing the placement of ice from the top of the asparagus crate to the bottom produced unsatisfactory results. It was found impossible to maintain a low temper-

ature, and deterioration in color and tenderness took place.

Packing the asparagus spears so that they were completely covered with tips just showing above the ice and in 4 ins. of No. 2 ice produced excellent results in both cases. With the temperature being maintained well below the critical temperature of 55°F. as recommended by Platenius (34) throughout the marketing operation, the asparagus arrived at the wholesale market in excellent condition.

Freshening asparagus in 2 ins. of ice water had no noticeable effect in lowering the temperature. As a matter of fact, the temperature in the experimental crates were higher than those in the control crate upon the arrival of the asparagus at the wholesale market.

It was found that precooling asparagus in an immersion-type hydrocooler was excellent for the removal of field heat but was not sufficient to maintain a low temperature during the marketing operation; however, the combination of hydrocooling and icing produced excellent results both from a standpoint of maintaining a low temperature and preventing deterioration. It was also noted that wetting the asparagus tips had no effect in causing a deterioration of the asparagus heads known as "stinkers".

Results would seem to indicate that the best

practical method of asparagus preparation for market is the combination of hydrocooling and icing. Lower temperatures were obtained using methods where the asparagus spears were packed completely in 4 ins. of ice. This method is not feasible from a commercial viewpoint because it would necessitate the changing of the type of asparagus crate now in general use.

Top and center icing of lettuce boxes in either combination or separately produced satisfactory results from both the standpoint of maintaining a low temperature and preventing deterioration. In the above-mentioned methods, 20 lbs. of No. 1 ice were used. As would be expected, the combination of top and center icing gave the best results. Placement of ice in the bottom of the lettuce boxes produced unsatisfactory results. It was found impossible to maintain a low temperature, and damage was caused by the lettuce being forced against the ice in the bottom of the box.

It was noted that if any of the preceding methods of icing the lettuce boxes were used plus a paper liner that the resulting temperature in the boxes was from five to fifteen degrees lower.

Precooling lettuce by means of an overhead-type hydrocooler for varying lengths of time produced excellent results as far as the removal of field heat

was concerned, but hydrocooling alone was insufficient to maintain a low temperature throughout the marketing operation. However, the combination of hydrocooling, icing, and enclosing the entire pack in a paper liner produced excellent results. This combination was by far the most satisfactory method tested. It is also a method which is very practical from a commercial viewpoint.

Precooling lettuce by means of cold air and icing produced satisfactory results from a standpoint of maintaining a low temperature. The length of time required to accomplish precooling, however, was from thirty to thirty-five hours--much too long to be of any use to local growers.

Top and center icing of celery boxes in either combination or separately produced satisfactory results from both the standpoint of maintaining a low temperature and preventing deterioration during the marketing operation. In the above-mentioned methods when the placement of ice was either at the top or center of the boxes, 10 lbs. of No. 5 ice was used. In those experiments that involved the combination of top and center icing, 5 lbs. of No. 5 ice was used. As would be expected, the combination of top and center icing produced the best results. Bottom icing of the celery boxes with 20 lbs. of No. 5 ice

gave unsatisfactory results. It was found impossible to maintain a low temperature, and damage was caused by the celery being forced against the ice in the bottom of the box.

Placement of ice in any one or combination of two or three positions--top, center and/or bottom of the celery boxes--and the enclosure of the entire pack in a single paper liner produced satisfactory results both in maintaining a low temperature and preventing deterioration.

Temperatures in paper lined crates dropped more rapidly and remained at a lower level than temperatures in unlined crates. This fact is evidenced by comparing Experiments I to V with Experiments IV to X. The amounts and placement of ice is the same in both groups of experiments; however, the only difference is that the last five were enclosed in a single paper liner. The lower temperature in the paper lined crates is undoubtedly the result of reducing air circulation through the crates. Paper liners also kept the produce in better condition by protecting it from handling, dirt and other mechanical injury.

Precooling celery in an immersion-type hydrocooler for varying lengths of time, top icing, and enclosing the entire pack in a single paper liner produced

excellent results. The longer the length of time of hydrocooling, the lower the temperature.

In the experiments with radishes, the main concern was the preservation of the radish leaves rather than the edible part of the radish. The radish itself is sturdy and can withstand high temperatures for a long period of time but the radish leaves are very succeptible to high temperstures. Such temperatures cause the radish leaves to wilt and turn yellow and become slimy.

The first experiment on radishes involved the placement of 20 lbs. of block ice between the two rows of radishes with the radish leaves facing towards the ice. This method produced unsatisfactory results with the temperature too high during the entire marketing operation. In the following two experiments, the amount and placement of ice was the same, but in one case, the radish leaves faced towards the ice and in the other, away from the ice. The entire pack was enclosed in a single paper liner. The results indicate that the single paper liner was responsible for the difference in the temperature thus making possible the arrival at the retail store of a much better pack in both cases.

Experiment IV was performed using the same amount and placement of ice as in the preceding three experiments with the radish leaves facing towards the ice.

The only difference was the enclosure of the entire pack in a double paper liner instead of a single paper liner.

This experiment using a double paper liner was performed in order to see if there was any advantage in using a double paper liner over that of a single paper liner. As the results on Table UU indicate, there is absolutely no advantage in using a double paper liner, or the advantage is so small that it could not be detected.

Precooling the radishes in an immersion-type hydrocooler for varying lengths of time--five, ten and fifteen minutes--and then icing the boxes with 20 lbs. of block ice placed between the two rows of radishes, the radish leaves arranged so that they faced away from the ice all produced unsatisfactory results. Hydrocooling lowered the temperature sufficiently but the amounts and type of ice used was unable to maintain the low temperature during the remainder of the marketing operation.

In the following three experiments, the lengths of hydrocooling was the same. The only difference was the use of 25 lbs. of No. 1 ice packed between the two rows of radishes instead of the 20 lbs. of block ice as used in the preceding three experiments.

This method proved fairly satisfactory with the temperature in the radish boxes being held just within a protective temperature range.

Hydrocooling the radishes for varying lengths of time and icing between the rows with either 20 lbs. of block ice or 25 lbs. of No. 1 ice and enclosing the entire pack in a single paper liner produced similar results with both methods being satisfactory from a standpoing of maintaining a low temperature and preventing deterioration during the marketing operation. Using 25 lbs. of No. 1 ice did cause a lowering of the temperature from four to eight degrees lower than that obtained by the use of 20 lbs. of block ice.

Controlled retail experiments performed in the laboratory very definitely indicated that a lower protective temperature could be maintained for vegetables in the retail store display using crushed ice.

It was found that ice displays of fresh vegetables in retail stores had consumer appeal. Iced produce minimizes weight loss, prevents wilting of commodity and the sales potential is great.

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